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TECHNICAL REPORT

STUDY OF OCEANOGRAPHIC CONDITIONS AS RELATED TO PROJECT POLYNYA

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ABSTRACT

The air-bubbling technique utilized by the Military Sea Transportation Service to prevent ice formation in North Star Bugt, Thule, Greenland is discussed. A proposed model of induced water circulation is presented. Physical processes impeding ice formation and growth in sea water are described. Oceanographic data collected in conjunction with the MSTS project are analyzed and presented in the appendixes.

FOREWORD

The formation of sea ice in northern waters often hastens the termination of shipping at Arctic harbors and sites. Retardation of ice growth can reduce or prevent damage to marine structures such as De Long pier at Thule, Greenland. A thorough understanding of physical effects which delay ice formation and slow ice growth is required. For these reasons, the experiment performed at Thule in 1959 is of considerable interest.

This report is a study of the effects of air-bubbling on the physical properties of the water adjacent to De Long pier. It attempts to formulate a working hypothesis for explaining the mechanism of the processes which retarded formation and growth of sea ice.

Conclusions expressed in this report may require revisions as additional data become available. All additional information which might amplify or modify this report will be welcomed by the Hydrographic Office.

E. C. STEPHAN
Rear Admiral, U. S. Navy
Hydrographer

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INTRODUCTION

Successful application of an air bubbling technique for preventing ice formation during the fall of 1958 enabled the Military Sea Transportation Service to extend the shipping season at Thule, Greenland. The normal shipping season extends from early July to early October. Shipping during the first half of July is usually dependent on icebreaker escort; shipping is ordinarily terminated prior to initial ice formation in autumn.

Adaptation of a method originally developed in Scandinavian countries for prevention of fresh-water freezing permitted maintenance of an ice-free area (polynya) adjacent to De Long pier despite normal ice formation in the surrounding waters of North Star Bugt (Bay). Safeguarded against becoming frozen-in at the pier, ships of the supply convoy remained at Thule until 25 October 1958 - the latest date on which MSTS had ever operated in such a northerly location. Success of the temporary installation prompted the Commander Military Sea Transportation Service Atlantic (COMSTSLANT) to formulate plans for the establishment of a permanently installed bubbling system at De Long pier.

In the fall of 1959, the U. S. Navy Hydrographic Office was requested to conduct oceanographic studies concurrently with the operation of the system in order to obtain information on physical processes impeding ice formation and growth in the bay. The overall operation was dubbed "Project Polynya".

NORTH STAR BUGT

North Star Bugt, approximately 3 square miles in area, recedes about 1-1/2 miles northeastward between Astro Pynt and Mount Dundas on the southern shore of Wolstenholme Fjord. The entrance of the bay, about 3/4 mile wide, is narrowed by De Long pier and a causeway which extend approximately 0.4 mile west-northwestward from Astro Pynt. The pier, 1,000 feet in length and 50 feet in width, adjoins the causeway and is parallel to it. Inside the entrance, the width of the bay increases to about 1 mile.

POLYNYA INSTALLATION 1959

Under the supervision of MSTSLANT, Canadian Underwater Demolition Unit BRAVO began installation of the bubbling system in North Star Bugt early in September 1959. Briefly, the system consists of perforated submarine polyethylene pipes which serve to conduct compressed air to the bottom of the bay and distribute it in the form of bubbles over a wide area (see Figure 1). An auxiliary alcohol-injection system is utilized to prevent or eliminate ice formation within the pipes.

Installation was completed on 27 September. Equipment was intermittently tested until appreciable ice began to form in the bay on 7 October, at which time full operation was begun.

ICE FORMATION AND GROWTH IN 1959

Ice was first observed on 16 September along the eastern fringe of North Star Bugt at a point where fresh water flows from the Pitufik River. By 24 September grease ice formed in an area northeast of the pier, where shallow water was observed to cool to the freezing point during low tide. This grease ice drifted westward with the next ebb tide. By 7 October a considerable amount of pancake ice had formed in the area northeast of the pier.

During the morning of 8 October a foehn wind arose with gusts to approximately 50 knots. The air temperature increased from 17° to 34° F. On the following morning, the bay was completely clear of ice and the surface water temperature had increased from -1.22° to -0.94° C.

During the morning of 10 October grease and pancake ice of small diameter formed over most of the area northeast of the pier. On 11 October a considerable amount of large pancake ice was observed drifting into the region from the south. The areas to the south, west, and northwest of the pier attained a coverage of approximately nine-tenths; no major ice formation was observed near the pier. By 15 October most of the bay was covered with young floes averaging approximately 10 feet in diameter. Ten-tenths concentration of young ice accumulated everywhere by 20 October except in the ice-free area adjacent to the pier.

DATA COLLECTION

Serial temperature, salinity, and current data were obtained at the locations shown in Figure 2. Temperature and salinity observations were taken between 9 September and 21 October.

Station 1 was occupied daily using a small hand winch mounted on the pier or by use of an oceanographic winch aboard the WESTWIND. For detailed observations, the polynya was divided into Stations 1A, 1B, and 1C as shown in Figure 3. Station 1D was designated at a point lying approximately 15 feet outside the polynya area and near the eastern end of the pier. Stations 2, 3, and 4 were occupied twice weekly using either a Greenland cruiser or an LCVP. Station 5 was occupied only on 15 September and Station 1D only on 13 October. Stations 6, 7, 8, and 9 were occupied weekly by the WESTWIND.

A 200-foot bathythermograph was used to measure temperature at all oceanographic stations. BT drops were made daily within the polynya area. Original plans had included daily observations at Stations 1, 1A, and 1B; however, presence of shipping often precluded data-collection at all 3 locations. A bucket thermometer was used in conjunction with each BT drop to obtain surface water temperature.

Meteorological observations obtained daily on the pier include wind speed and direction, wet and dry bulb air temperature, cloud cover and type, visibility, sea state, and state of weather. In addition, pertinent data were extracted from the weather log maintained at Thule Air Base for analysis (Appendix V). Data on tidal currents were obtained by suspending 3 Roberts radio current meters at depths of 6, 26, and 54 feet from an anchored radio buoy. Water depth at each location was 12 fathoms. Signals transmitted from the buoy were recorded at 30-minute intervals by a monitoring station aboard the WESTWIND. Current meter Station 10 was occupied from 1830Z, 25 September to 2100Z, 26 September; Station 11 was occupied from 1200Z, 6 October to 1930Z, 13 October 1959. Current data were not tabulated, because the recorded results either approximated the threshold value of the current meter (0.2 knot) or were unreadable.

A supplementary survey conducted during April 1960 by Hydrographic Office ice observers yielded late-winter temperature data at Stations 1 and 2 (Appendix III).

DATA ANALYSIS

Oceanographic conditions at each station were examined for factors contributing to the formation and growth of ice. Surface temperatures indicating heat loss at the sea surface and physical properties showing the distribution of heat loss throughout the water column were studied. Data obtained outside the polynya were compared to those obtained at Station 1 in order to determine the effect of the bubbling system on the oceanographic structure.

Reversal of the heat budget had occurred prior to inception of the oceanographic survey. Except for interruption by the foehn on 8 October, progressive cooling was observed at all depths. The temperature rise shown by the tabulated data for 9, 10, and 11 October was observed at Station 1. Upon resumption of the cooling process, surface temperature outside the bubbled area decreased rapidly. The freezing point was attained on 13 October.

A study of the salinity structure indicates spatial and temporal fluctuations of surface values and depth of the isohaline layer. A plot of the surface salinity values at Station 1 is presented in Figure 4. The portion of the plot constructed from values for early September indicates that a certain periodicity may exist. The pronounced increase during the latter part of September is attributed to cessation of runoff.

Data obtained at Station 3 on 18 September and 12 October are plotted in Figures 5 and 6. The surface water temperature on 18 September was 0.64° C; temperature maximum of 0.72° C occurred at 9 and 20 meters. The surface salinity was 31.23 °/oo. Convection extended to a depth of only a few meters.

By 12 October the surface water had cooled to -1.32° C; the warmest water was at the bottom. The temperature maximum of -0.62° C was observed at a depth of 33 meters. The surface salinity had increased to 32.34 °/oo, and convective mixing had produced an isohaline layer in the upper 15 meters. The calculated freezing point of the surface is -1.76° C.

The density gradient below the 15-meter level, although weak, has significant relevance to the bubbling system. Theoretical ice-potential calculations using the data of the deeper stations show that, prior to initial ice formation , thermohaline convection takes place to a depth of approximately 15 meters. Consequently, the water below this level temporarily serves as a source of sensible heat. However, as ice forms, the salinity of the upper layer increases, resulting in greater density and an increase in depth of convective mixing. As the density gradient weakens and eventually disappears, cooling to the freezing point will occur throughout the water column. At the known average rate of heat loss from the sea surface in the latitude of Thule, the entire supply of warm water will be eliminated within two weeks after initial formation of ice.

The heat content of air issuing from the compressors is considerable. An appreciable amount of heat is possibly introduced into the bottom water adjacent to the pier when compressed air cools in the polyethylene pipes; however, the data do not indicate a temperature differential attributable to this source within the bubbler field. A layer of dirt covering four steel feed pipes provides insulation; however, heat loss through the rubber feed hoses is great. Between the point where these hoses connect to the steel pipes and the point where they enter the water, melting of snow within a radius of approximately 2 feet was observed. Ice formation due to moisture condensate in the underwater sections of the feed pipes was removed by alcohol injection.

The effectiveness of the bubbler system, when warmer bottom water is available, is manifested by the temperature data in Table I.

TABLE I
13 October 1959

STATION 1		STATION 1D	
Depth (meters)	Temp. (°C)	Depth (meters)	Temp. (°C)
0.0	-1.09	0	-1.76
3.5	-1.08	3	-1.60
6.5	-1.06	6	-1.25
9.5	-1.06	9	-1.24

The surface temperature at Station 1D, located immediately outside the bubbler field, shows that the surface water had cooled to the freezing point. Despite ice formation around the perimeter of the agitated area, the data obtained at Station 1 show the surface temperature to be 0.67° C above the freezing point. The data for Station 1D are assumed to be indicative of temperature data that would have been observed at Station 1 had the bubbler system not been in operation. The data of 13 October plus the profiles for Stations 2 and 3 on 12 October indicate that water from depths greater than 15 meters is circulated into the agitated water columns adjacent to the pier.

Proof that the bubble system acts as a huge pump capable of performing work on the surrounding subsurface water is provided by comparison of data presented in Tables II and III.

TABLE II
11 October 1959

STATION 1

Depth (meters)	Temp. (° C)	Salinity (°/oo)	σ_t
0.0	-0.90	32.42	26.08
3.5	-0.91	32.42	26.08
6.5	-0.91	32.42	26.08
9.5	-0.89	32.43	26.09

TABLE III
12 October 1959

STATION 2

Depth (meters)	Temp. (° C)	Salinity (°/oo)	σ_t
0	-1.42	32.32	26.02
5	-1.40	32.32	26.02
15	-1.42	32.32	26.02
22	-0.69	32.52	26.16
24	-0.78	32.52	26.16

The density of the agitated water column in Table II is greater than the density to at least 15 meters in Table III; therefore, work was performed by the system in raising water through a vertical distance in excess of 15 meters. Comparison of salinity and density data of Table II and the plotted curves of Figure 6 reveals that water similar to the entire water column at Station 1 is found at 20 meters at Station 3, indicating that the water was raised at least 20 meters.

The eventual cooling of the entire water column to the freezing point indicates that vertical transport of sensible heat from depth was not a factor in the maintenance of the artificially created polynya, except during the initial stage of the ice formation. Consequently, an understanding of the physical process involved must be sought along other lines.

Elementary ice particles are probably disk-shaped and devoid of crystalline form. Ordinarily they flocculate and grow into true crystals. The turbulent energy of the induced currents may destroy the crystals before they enlarge or may effectively prevent crystalline growth about ice nuclei. Ice particles at the surface of the bubbled area are rapidly swept from regions of divergence into regions of convergence where, by means of descending currents, they are transported beneath the surface to be eventually dispersed from the polynya area.

Hydrographic Office ice observers, stationed at Thule Air Base throughout the winter of 1959-60, noted that the polynya gradually narrowed; by the end of December width ranged from 12 feet at the eastern end to 50 feet at the western end, where an auxiliary air hose was used to augment the bubbling activity by inducing more vigorous currents. Dimensions of the ice-free area gradually increased during spring as the air temperature rose to approximately 0° F.

A plot of sea ice tensile strength versus temperature (Assur, 1958) shows a marked increase of strength as the temperature of the ice drops below -9.2° F. At this temperature sodium chloride is precipitated from the brine pockets in the ice. During periods of extremely low air temperature in winter, the weakest point of the ice should be at its undersurface where the temperature approaches that of the water.

Measurements made during April 1960 show that ice thickness directly above one of the polyethylene pipes averaged approximately 10 inches while thicknesses ranged between 41 and 44 inches at locations 60, 200, and 375 yards north-northeast of the pier. Abrasive action of induced currents apparently inhibited ice growth in zones of most vigorous flow.

The erosive capability of water currents is manifested by recent experiments in the Antarctic. Specially shaped propellers driven by small motors were suspended through holes in the ice of McMurdo Sound. The propellers created vigorous currents which eroded the ice from below. A 10-horsepower device reportedly required 183 hours to open an area 30 by 85 feet in 8-foot-thick ice. An additional swath of ice 200 feet long was eroded to a thickness of 18 inches; soon afterward, it fell through.

Analysis of data obtained with the Roberts current meters revealed no permanent current. Mass transport of water in the area was attributed to tidal action. Peak tidal current speed was approximately 0.2 knots (based on threshold value of the instrument).

CONCLUSIONS

The bubbling system operates as a huge pump capable of performing work on contiguous subsurface water. The rising streams of bubbles initiate a system of circulatory cells which extend from the bubbled region into adjacent water. Water from depths exceeding 15 meters is circulated into the agitated columns adjacent to the pier and brought to the surface.

At the time of initial ice formation in 1959, convective mixing had occurred throughout the upper 15 meters of North Star Bugt. The density gradient below the 15-meter level gradually weakened with ice growth, and the entire water column cooled to the freezing point. After elimination of the warm water supply, maintenance of an open water area adjacent to the pier was attributed to the ice-dispersive and erosive activity of the induced currents coupled with the possibility that the turbulent energy also sufficed to prevent crystalline growth about ice nuclei. Efficiency of the system varied directly with turbulence.

Considerable narrowing of the polynya by mid-winter was attributed to marked increase of tensile strength with consequent increased resistance to erosive action of the induced currents as the temperature of the ice dropped below -9.2° F. Vertical growth of the newly formed ice cover within the bubbled area was inhibited by this erosive action because the undersurface of the ice is weakest when its temperature equals that of the water. Increase in the dimensions of the ice-free area was observed to concur with an increase of air temperature to approximately 0° F in early spring. This increase was attributed to marked decrease of tensile strength with consequent decreased resistance to erosion as the temperature of the ice rose above -9.2° F.

Unique properties of fresh water make the bubbling system highly suitable for lakes and to a somewhat lesser extent for brackish estuaries. The system is less effective in salt water, because maximum density of water with salinity in excess of 24.7 $^{o}/oo$ is attained at the freezing point. However, factors other than the upward transport of warm water, as previously discussed, also contribute to the mainenance of an ice-free area.

In regions where upward circulation of sensible heat is not a factor, maintenance of an ice-free area is predominantly dependent upon speed and intensity of the induced currents.

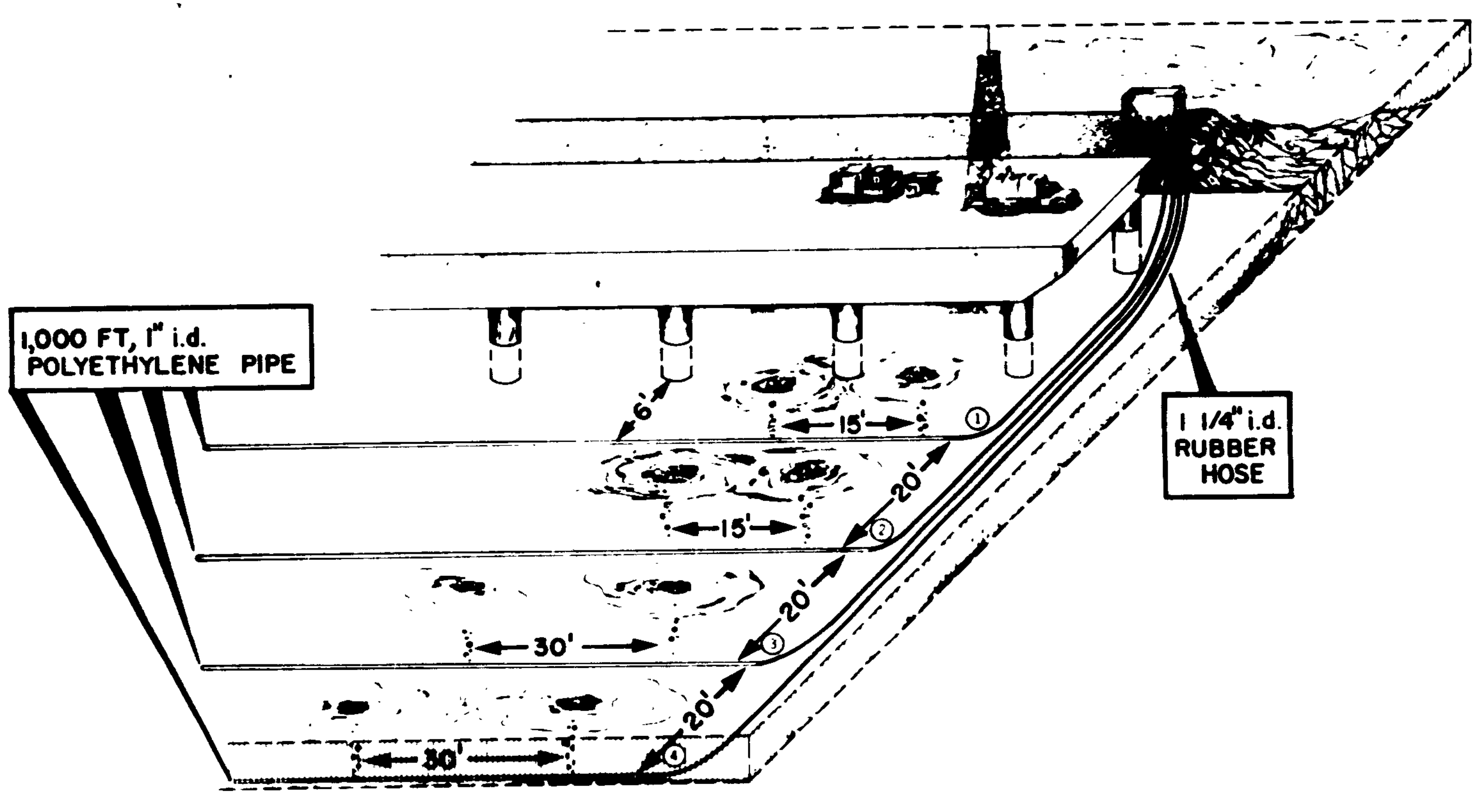

FIGURE 1 COMPRESSED—AIR BUBBLE SYSTEM AT DE LONG PIER

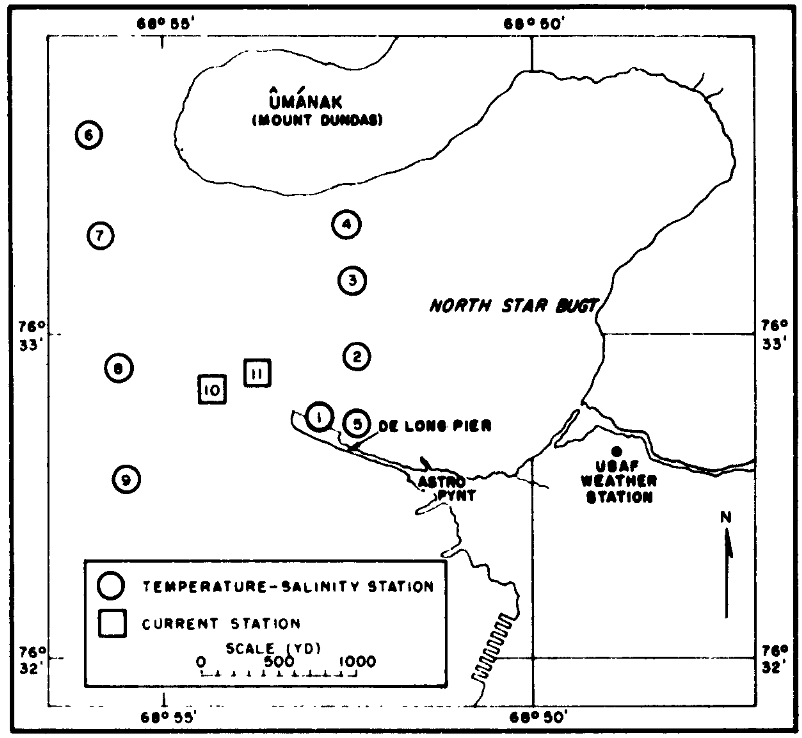

FIGURE 2 LOCATION CHART OF OCEANOGRAPHIC STATIONS, 1959

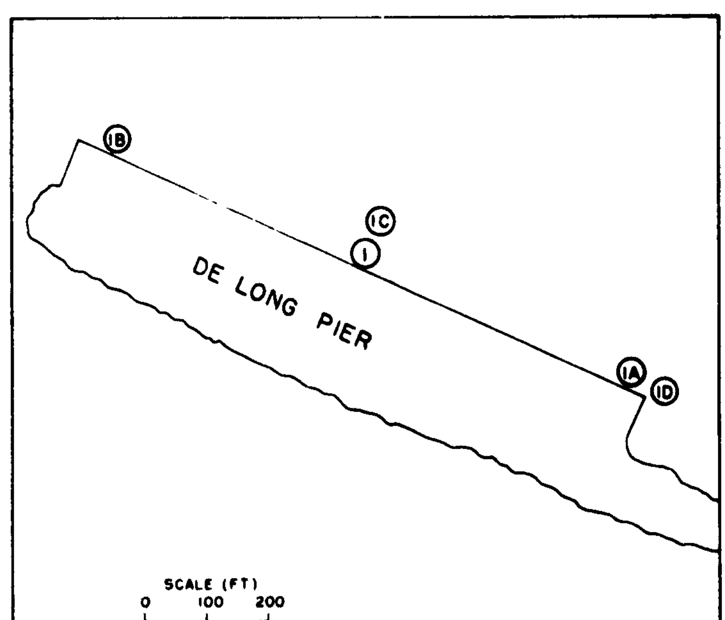

FIGURE 3 LOCATION OF OCEANOGRAPHIC STATIONS IN VICINITY OF DE LONG PIER, 1959

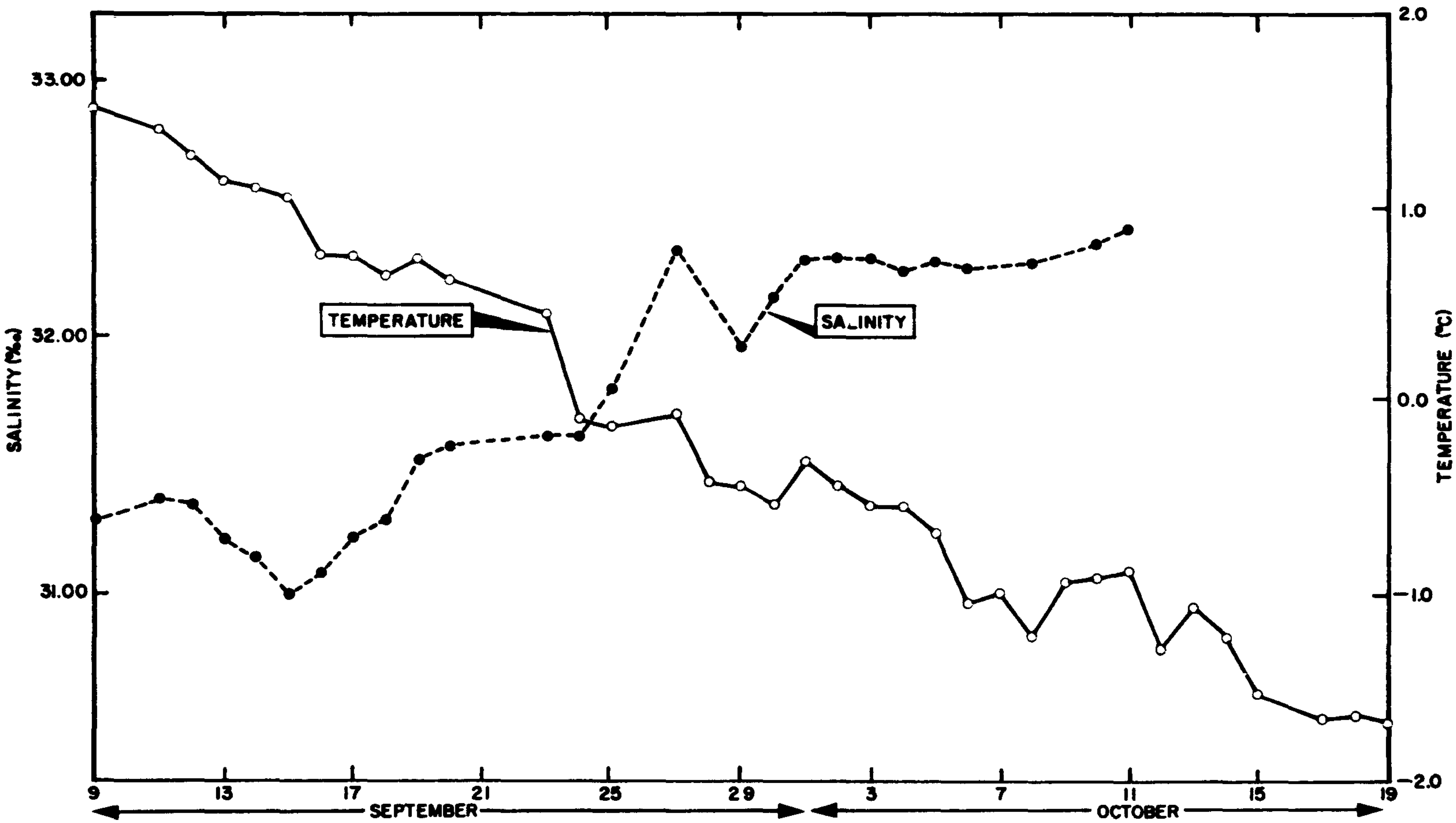

FIGURE 4 SURFACE TEMPERATURE AND SALINITY AT STATION 1, 9 SEPTEMBER–19 OCTOBER 1959

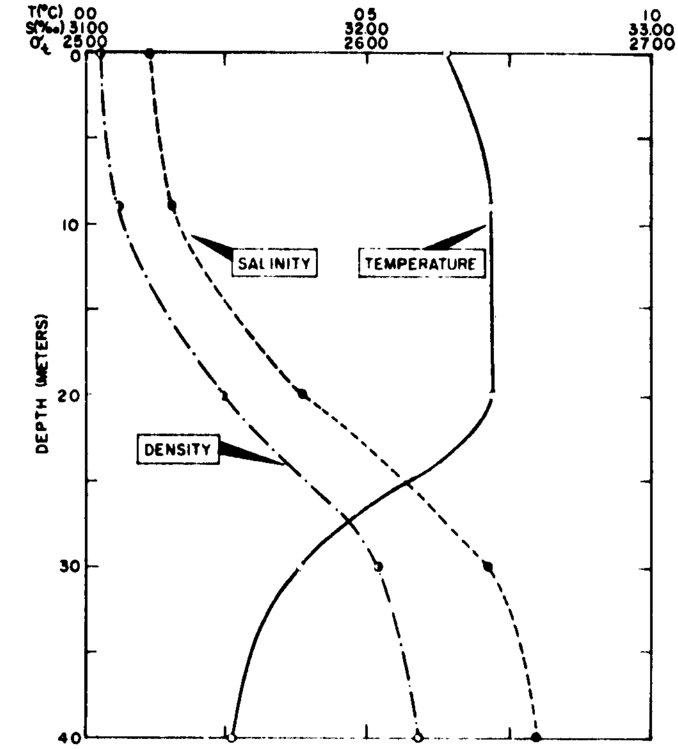

FIGURE 5 TEMPERATURE, SALINITY, AND DENSITY PROFILES AT STATION 3, 18 SEPTEMBER 1959

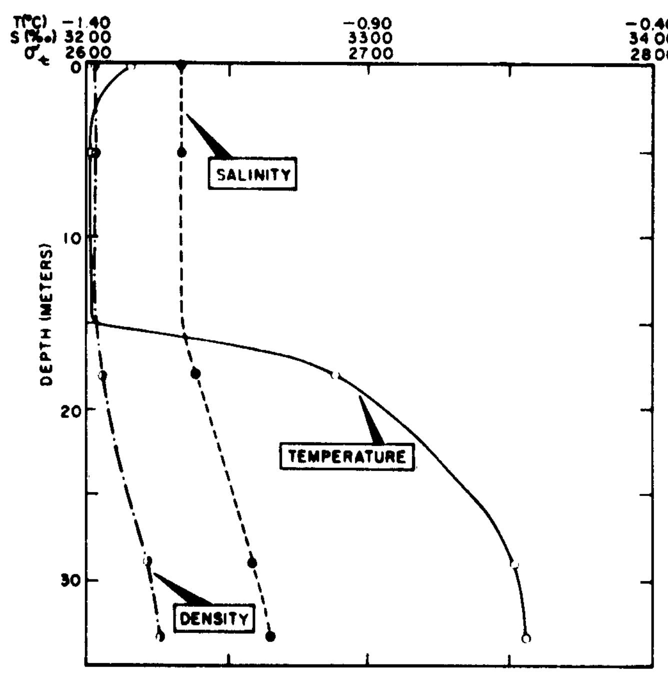

FIGURE 6 TEMPERATURE, SALINITY, AND DENSITY PROFILES AT STATION 3, 12 OCTOBER 1959

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APPENDIX I

MODEL OF THE POLYNYA CIRCULATORY SYSTEM

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MODEL OF THE POLYNYA CIRCULATORY SYSTEM

Figure 7 illustrates streamlines generated by the motion of a solid sphere in an infinite mass of frictionless fluid. If we take the origin at the center of the sphere and the x axis in the direction of motion, the normal velocity (V_n) at the surface of the sphere is $U \cos \theta$, where U is the velocity of the center.

Lamb shows that the stream function due to the sphere is

$$\psi = -\frac{1}{2} U \frac{a^3}{r} \sin^2 \theta$$

where a is the radius of the sphere, r is the radius vector from the center to points on or exterior to the sphere ($r \geq a$), and θ is the angle between the radius vector and the x axis. At any given instant the trajectories of the fluid particles are tangent to the streamlines.

The total flux through a curved surface S is $\int_S V_n dS$. Arbitrarily making this value equal to $-2\pi\psi$, we have

$$-2\pi\psi = \int_S V_n dS.$$

In the case where S is the surface of the above sphere ($r=a$) substitution of $2\pi y ds$ for dS yields

$$-2\pi\psi = \int_s V_n \, 2\pi y ds,$$

where ds, as shown in Figure 8, is an infinitesimal length of arc subtended by an infinitesimal angle, $d\,\theta$, on the surface S. Substitution of $U \cos \theta$, $a \sin \theta$, and $a\,d\theta$ for V_n, y, and ds, respectively, and integrating between the limits 0 and θ yields

$$-\psi = Ua^2 \int_0^\theta \cos \theta \sin \theta \, d\theta.$$

Therefore,

$$\psi = -\frac{1}{2} Ua^2 \sin^2 \theta.$$

Lamb shows that the stream function from an n pole is given by

$$\psi = K \frac{\partial^{n-1} \cos \theta}{\partial x^{n-1}}.$$

Since the sphere acts as a dipole,

$$\psi = K \frac{\partial \cos \theta}{\partial x} = \frac{K}{r} \sin^2 \theta.$$

From the boundary value $r=a$,

$$\frac{K}{a} \sin^2 \theta = -\frac{1}{2} Ua^2 \sin^2 \theta.$$

Therefore,

$$K = -\frac{1}{2} U a^3 ,$$

and for the general case; i. e., $r \geq a$

$$\psi = -\frac{1}{2} U \frac{a^3}{r} \sin^2 \theta .$$

A model of the polynya circulatory system can be formulated from the idealized case by adaptation of the principles to the bubbling system. Considering the motion of each ascending bubble to be directed along the positive-downward Z axis, there will be a streamline coincident with the Z axis and a vertical flow of water particles. Ascending motion, represented by a negative vertical velocity, creates divergence at the surface. Approximately midway between bubble streams is a region of convergence with consequent descending motion, clearly discernible in Figure 9.

Surface water beyond the pipe furthest from the pier flows outward to a distance determined by the horizontal momentum of the water particles.

The data show greater density in water brought to the surface by the bubble activity during the pre-freezeup and initial freezeup periods. Consequently, as the higher density surface water flowing outward from the divergence zone above pipe #4 suffers a gradual decrease in the horizontal component of the velocity vector, the vertical component increases. From the point where the horizontal component becomes zero, descending motion extends to depths where divergence directs a horizontal component toward the pier.

The proposed model of the polynya circulatory system is presented in Figure 10. This cross-sectional view shows the eastern ends of the polyethylene pipes; arrows indicate principal paths of the water particles.

The author is indebted to Dr. Lloyd Simpson of the Hydrographic Office for advice and assistance in application of hydrodynamic principles in development of this idealized model of the bubbling system.

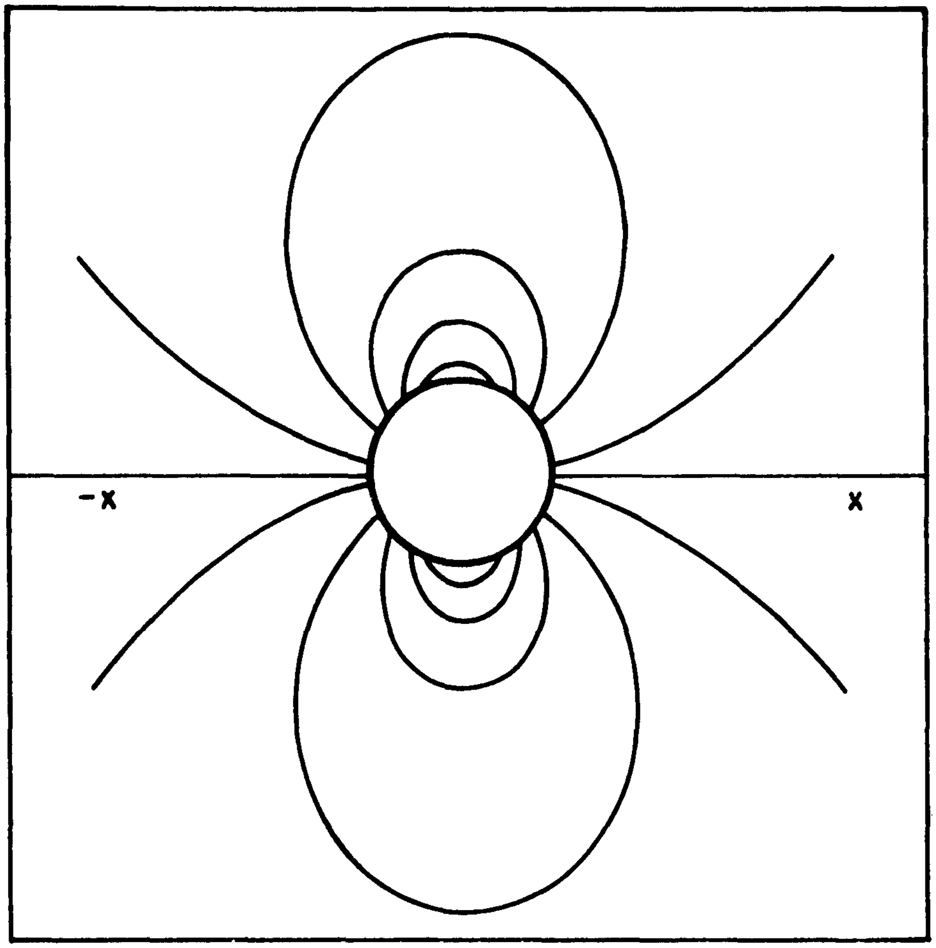

FIGURE 7 STREAMLINES PRODUCED BY A SOLID SPHERE MOVING THROUGH AN INFINITE MASS OF FRICTIONLESS FLUID.

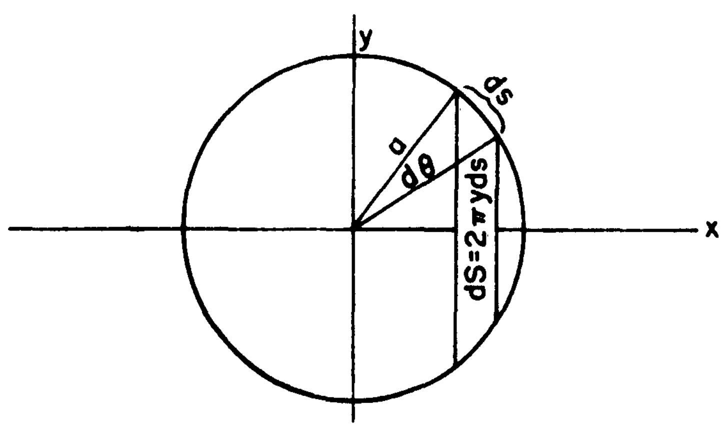

FIGURE 8

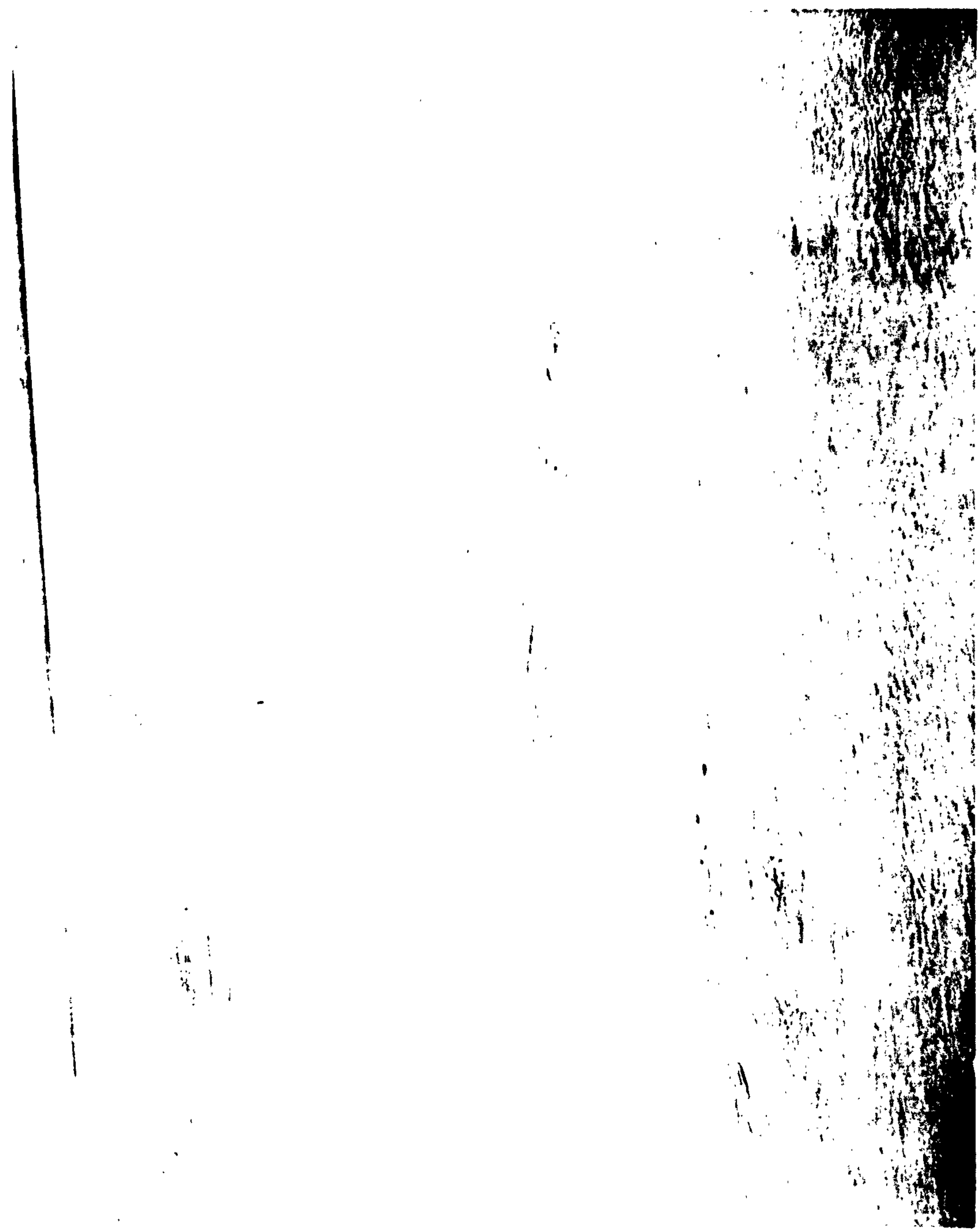

FIGURE 9 FLOW PATTERN AT THE POLYNYA SURFACE

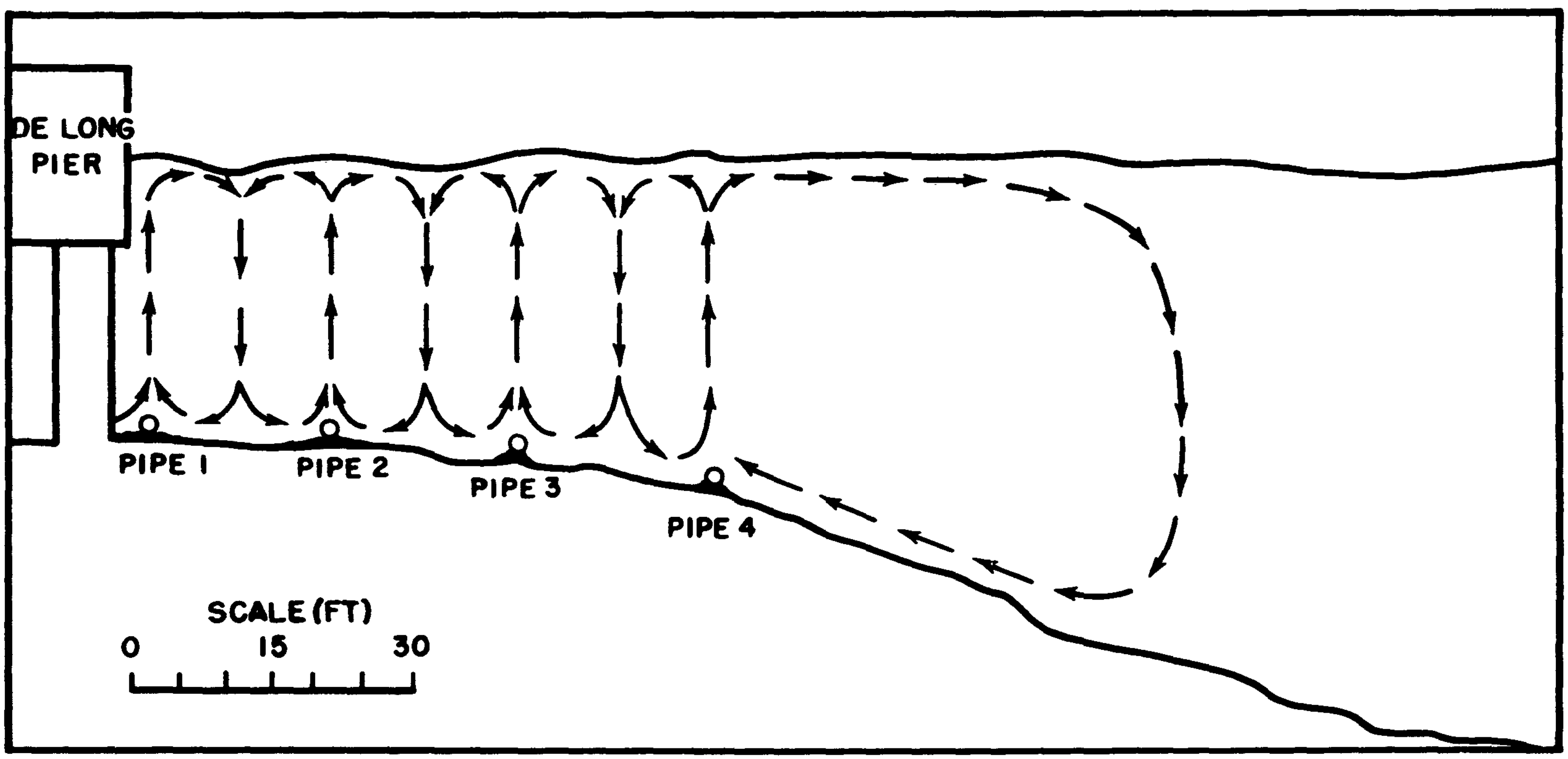

FIGURE 10 VERTICAL CROSS SECTION SHOWING CIRCULATION PRODUCED BY BUBBLING SYSTEM IN NORTH STAR BUGT

APPENDIX II

OCEANOGRAPHIC PROGRAM - 1960

APPENDIX II

OCEANOGRAPHIC PROGRAM - 1960

A program of oceanographic data collection similar to that of 1959 was conducted during the fall of 1960. Observations of the formation and growth of ice on North Star Bugt were initiated on 6 October. On this date grease and pancake ice were observed in the shallow water area northeast of De Long pier. By 30 October most of the bay was covered with drifting floes of young ice approximately one inch thick. Strong easterly winds with gusts to 50 knots completely cleared the bay of ice on 3 November. Ice began to form again on 5 November, and a ten-tenths concentration of young ice was attained by 7 November with exception of an ice-free area adjacent to the pier.

Commencing 8 October and terminating 7 November, serial temperature and salinity data were obtained at 4 stations. The locations of Stations 1 and 2 concurred with the locations of Stations 1 and 2 for 1959 as shown in Figure 2. Station 3 was located approximately 100 feet north of Station 1, while Station 4 was located just off the shoreward end of the pier. The data are presented in Appendix VI. Surface temperature and salinity values for Station 1 are plotted in Figure 11.

Data were taken at Station 4 for comparison of the oceanographic structure outside the bubbled area with that of the water column at Station 1 during the early period of ice growth on the bay. Occupation of Station 4 necessitated breaking through the ice cover. Sharp rises in surface water temperature were observed on 21 and 24 October; easterly winds with speed maximums of 51 and 48 knots, respectively, were recorded on these dates. Although no data below the 10-meter level are available, it is evident, as indicated by the temperature and salinity data presented in Appendix VI, that the wind affected vertical mixing throughout North Star Bugt.

On 10 October, the surface temperature at Station 1 was -1.54° C; the salinity was 32.30 ‰. On 15 October, the surface temperature at Station 2 was -1.77° C with grease ice forming in the area; surface temperature in the ice-free bubbled area was -1.68° C. Surface values of -1.81° C and 32.82 ‰ were recorded at Station 1 on 29 October; the bubbling system was not in operation, and a considerable amount of grease and slush ice was forming on the bay.

Activation of the bubbling system on the following day resulted in quick dispersal of all ice from the bubbled area. Light grease and slush ice being swept from divergent regions and transported beneath the surface in convergent regions confirmed one aspect of the proposed model of induced circulation. Surface temperature of -1.82° C within the bubbled area indicates supercooling, since the calculated freezing point was -1.79° C.

When compared to data obtained at Station 1, those obtained at Station 4 on 5, 6, and 7 November indicate that vertical transport of sensible heat was not a factor in maintenance of the ice-free area adjacent to the pier. The temperature beneath the ice outside the bubbled area was identical to that of the isothermal water column at Station 1.

Subsequent history of the polynya was similar to that of the previous winter.

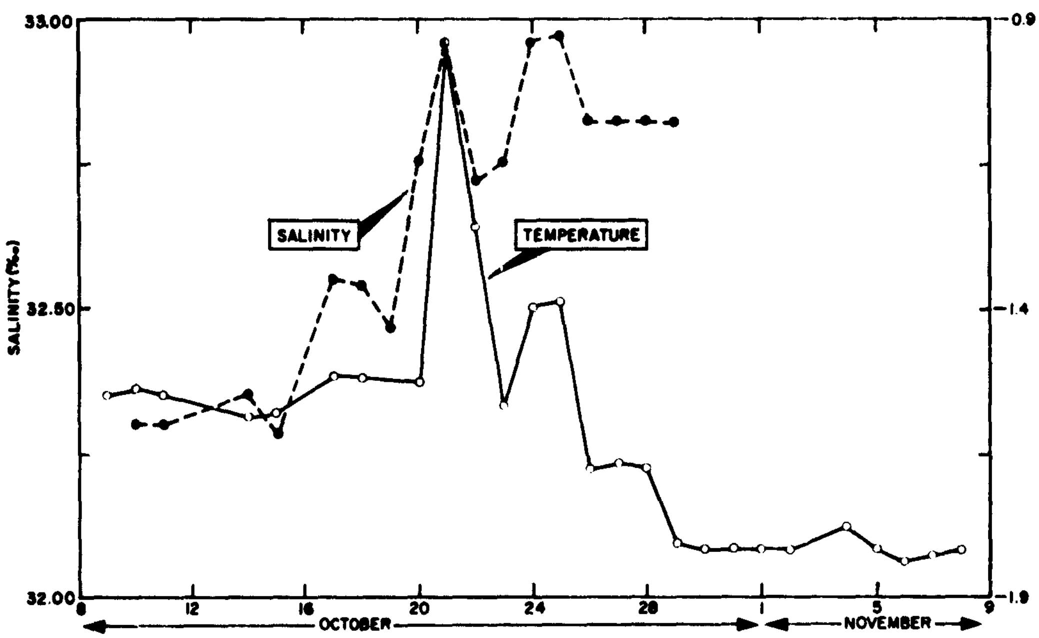

FIGURE 11 SURFACE TEMPERATURE AND SALINITY AT STATION 1, 8 OCTOBER-9 NOVEMBER 1960

APPENDIX III

OCEANOGRAPHIC DATA

INNER STATIONS, 1959

APPENDIX III - OCEANOGRAPHIC DATA (INNER STATIONS), 1959

CAST 1 LOCATION Station 1
DATE 9 IX 59 GMT 2100
DEPTH 9 M

Depth M	T °C	S ‰	σ_t
0.0	1.53	31.26	25.03
2.5	1.47	31.26	25.04
4.5	1.38	31.28	25.06
6.5	1.38	31.28	25.06
8.5	1.36	31.28	25.06

CAST 2 LOCATION Station 1
DATE 11 IX 59 GMT 2000
DEPTH 10 M

Depth M	T °C	S ‰	σ_t
0	1.42	31.36	25.12
2	1.37	31.36	25.12
5	1.37	31.36	25.12
7	1.37	31.36	25.12
10	1.35	—	—

CAST 3 LOCATION Station 1
DATE 12 IX 59 GMT 1250
DEPTH 10 M

Depth M	T °C	S ‰	σ_t
0	1.28	31.34	25.11
3	1.28	31.34	25.11
5	1.28	31.34	25.11
8	1.26	31.34	25.12
10	—	31.35	—

CAST 4 LOCATION Station 1
DATE 13 IX 59 GMT 1445
DEPTH 10 M

Depth M	T °C	S ‰	σ_t
0.0	1.15	31.20	25.01
3.0	1.16	31.20	25.01
5.0	1.16	31.21	25.02
8.0	1.16	31.21	25.02
9.5	1.16	31.21	25.02

CAST 5 LOCATION Station 1*
DATE 14 IX 59 GMT 1235
DEPTH 10 M

Depth M	T °C	S ‰	σ_t
0.0	1.11	31.12	24.95
2.0	1.13	31.13	24.95
5.0	1.13	31.20	25.01
7.5	1.13	—	—
9.5	1.44	31.25	25.03
9.5**	1.16	31.17	24.98

* Bubbling system had been in operation for about 5 minutes just prior to obtaining the water samples

** Sample obtained at 1350Z - bubbling system not in operation

CAST 6 LOCATION Station 2
DATE 15 IX 59 GMT 1345
DEPTH 19.5 M

Depth M	T °C	S ‰	σ_t
0.0	0.97	31.01	24.87
2.5	0.98	31.02	24.87
9.5	1.08	31.08	24.92
13.5	1.08	31.12	24.95
17.5	1.09	31.15	24.97

CAST 7 LOCATION Station 4
DATE 15 IX 59 GMT 1500
DEPTH 39 M

Depth M	T °C	S ‰	σ_t
0	1.02	30.96	24.82
5	1.03	30.99	24.85
17	1.05	31.12	24.95
27	0.80	31.95	25.63
37	0.35	32.63	26.20

CAST 8 LOCATION Station 3
DATE 15 IX 59 GMT 1556
DEPTH 42 M

Depth M	T °C	S ‰	σ_t
0	1.02	31.04	24.89
10	1.03	31.09	24.93
20	1.05	31.21	25.02
30	0.53	32.31	25.93
40	0.23	32.74	26.29

CAST 9 LOCATION Station 5
DATE 15 IX 59 GMT 1640
DEPTH 10 M

Depth M	T °C	S ‰	σ_t
0	1.04	30.98	24.84
3	1.04	30.99	24.85
6	0.99	30.99	24.85
8	0.96	30.99	24.85

CAST 10 LOCATION Station 1C
DATE 15 IX 59 GMT 1713
DEPTH 13.5 M

Depth M	T °C	S ‰	σ_t
0	1.06	30.99	24.85
3	1.06	30.99	24.85
10	0.99	30.99	24.85
13	0.99	30.99	24.85

CAST 11 LOCATION Station 1
DATE 16 IX 59 GMT 1345
DEPTH 10 M

Depth M	T °C	S ‰	σ_t
0.0	0.76	31.07	24.92
2.5	0.78	31.07	24.92
5.0	1.02	31.17	24.99
7.5	0.97	31.40	25.18
9.5	0.96	31.45	25.22

CAST 12 LOCATION Station 1C
DATE 17 IX 59 GMT 1222
DEPTH 13 M

Depth M	T °C	S °/oo	σ_t
0	0.79	31.21	25.04
3	0.78	31.22	25.05
5	0.87	31.32	25.12
8	0.81	31.45	25.23
12	0.80	31.53	25.29

CAST 13 LOCATION Station 1C*
DATE 17 IX 59 GMT 2107
DEPTH 13 M

Depth M	T °C	S °/oo	σ_t
0	0.75	31.32	25.13
3	0.75	31.33	25.14
5	0.76	31.33	25.14
8	0.74	31.34	25.14
12	0.74	31.35	25.15

CAST 14 LOCATION Station 1C
DATE 18 IX 59 GMT 1237
DEPTH 13 M

Depth M	T °C	S °/oo	σ_t
0	0.66	31.24	25.07
3	0.70	31.28	25.10
5	0.78	31.37	25.17
8	0.75	31.41	25.20
12	0.71	31.45	25.23

* Bubbling system in operation

CAST 15 LOCATION Station 4
DATE 18 IX 59 GMT 1242
DEPTH 38 M

Depth M	T °C	S °/oo	σ_t
0	0.66	31.25	25.08
5	0.72	31.28	25.10
17	0.75	31.57	25.33
27	0.37	32.45	26.05
37	0.22	32.63	26.21

CAST 16 LOCATION Station 3
DATE 18 IX 59 GMT 1410
DEPTH 41 M

Depth M	T °C	S °/oo	σ_t
0	0.64	31.23	25.06
9	0.72	31.31	25.12
20	0.72	31.77	25.49
30	0.38	32.43	26.04
40	0.26	32.60	26.18

CAST 17 LOCATION Station 2
DATE 18 IX 59 GMT 1500
DEPTH 26 M

Depth M	T °C	S °/oo	σ_t
0	0.64	31.22	25.05
10	0.77	31.35	25.15
15	0.77	31.47	25.25
20	0.77	31.66	25.40
25	0.68	31.93	25.62

CAST 18 LOCATION Station 1C
DATE 19 IX 59 GMT 1205
DEPTH 13 M

Depth M	T °C	S °/oo	σ_t
0	0.74	31.50	25.27
3	0.70	31.51	25.28
5	0.74	31.52	25.29
8	0.71	31.52	25.29
12	0.70	31.58	25.34

CAST 19 LOCATION Station 1C
DATE 20 IX 59 GMT 1418
DEPTH 13 M

Depth M	T °C	S °/oo	σ_t
0	0.63	——	——
3	0.64	31.56	25.33
5	0.64	31.56	25.33
8	0.61	31.60	25.36
12	0.57	31.96	25.65

CAST 20 LOCATION Station 2
DATE 21 IX 59 GMT 1145
DEPTH 28 M

Depth M	T °C	S °/oo	σ_t
0	0.38	31.50	25.29
5	0.42	31.52	25.30
12	0.54	31.71	25.45
22	0.34	32.38	26.00
27	0.28	32.50	26.10

CAST 21 LOCATION Station 3
DATE 21 IX 59 GMT 1235
DEPTH 35 M

Depth M	T °C	S °/oo	σ_t
0	0.35	31.51	25.30
10	0.55	31.64	25.39
24	0.32	32.46	26.07
34	0.08	32.71	26.28
35	0.07	32.76	26.32

CAST 22 LOCATION Station 4
DATE 21 IX 59 GMT 1336
DEPTH 36 M

Depth M	T °C	S °/oo	σ_t
0	0.34	31.52	25.31
15	0.51	31.95	25.65
25	0.29	32.47	26.07
30	0.16	32.64	26.22
35	0.13	32.69	26.26

CAST 23 LOCATION Station 1C
DATE 23 IX 59 GMT 1638
DEPTH 14 M

Depth M	T °C	S °/oo	σ_t
0	0.44	31.60	25.37
4	0.21	31.61	25.39
7	0.24	31.62	25.39
10	0.34	31.68	25.44
13	0.34	31.68	25.44

CAST 24 LOCATION Station 1C
DATE 24 IX 59 GMT 1202
DEPTH 13 M

Depth M	T °C	S °/oo	σ_t
0	-0.10	31.60	25.39
3	-0.11	31.60	25.39
6	-0.07	31.61	25.40
9	0.08	31.69	25.46
13	0.25	——	——

CAST 25 LOCATION Station 2
DATE 24 IX 59 GMT 1702
DEPTH 28 M

Depth M	T °C	S °/oo	σ_t
0	-0.10	31.61	25.40
12	0.39	32.21	25.87
18	0.34	32.33	25.96
23	0.17	32.56	26.15
27	0.04	32.62	26.21

CAST 26 LOCATION Station 3
DATE 24 IX 59 GMT 1748
DEPTH 42 M

Depth M	T °C	S °/oo	σ_t
0	-0.12	31.60	25.39
13	0.41	32.12	25.79
26	0.08	32.71	26.28
36	-0.13	32.94	26.47
41	-0.13	32.94	26.47

CAST 27 LOCATION Station 4
DATE 24 IX 59 GMT 1834
DEPTH 37 M

Depth M	T °C	S °/oo	σ_t
0	-0.08	31.61	25.40
10	0.34	31.86	25.58
20	0.20	32.53	26.13
30	0.02	32.73	26.30
36	-0.16	32.95	26.48

CAST 28 LOCATION Station 1B
DATE 25 IX 59 GMT 1823
DEPTH 10 M

Depth M	T °C	S °/oo	σ_t
0	-0.14	31.78	25.56
3	-0.12	——	——
6	-0.11	31.79	25.55
10	-0.11	31.80	25.55

CAST 29 LOCATION Station 1
DATE 27 IX 59 GMT 1750
DEPTH 9 M

Depth M	T °C	S °/oo	σ_t
0.0	-0.08	32.31	25.96
3.5	-0.10	32.33	25.98
6.5	-0.11	32.33	25.98
8.5	-0.12	32.35	26.00

CAST 30 LOCATION Station 2
DATE 28 IX 59 GMT 1340
DEPTH 27 M

Depth M	T °C	S ‰	σ_t
0	-0.60	31.95	25.69
6	-0.45	32.13	25.83
15	-0.33	32.26	25.93
22	-0.13	32.39	26.03
26	-0.13	32.44	26.07

CAST 31 LOCATION Station 4
DATE 28 IX 59 GMT 1425
DEPTH 34 M

Depth M	T °C	S ‰	σ_t
0	-0.54	32.02	25.75
6	-0.43	32.13	25.83
20	-0.29	32.33	25.99
32	-0.05	32.71	26.28
34	-0.11	—	—

CAST 32 LOCATION Station 3
DATE 28 IX 59 GMT 1528
DEPTH 37 M

Depth M	T °C	S ‰	σ_t
0	-0.54	31.98	25.72
6	-0.47	32.11	25.82
24	-0.04	32.40	26.03
32	-0.17	32.63	26.22
36	-0.28	33.05	26.57

CAST 33 LOCATION Station 1
DATE 28 IX 59 GMT 1925
DEPTH 9 M

Depth M	T °C	S ‰	σ_t
0.0	-0.43	—	—
3.5	-0.40	—	—
6.5	-0.32	—	—
8.5	-0.30	—	—

CAST 34 LOCATION Station 1
DATE 29 IX 59 GMT 1847
DEPTH 9 M

Depth M	T °C	S ‰	σ_t
0	-0.46	31.95	25.69
3.5	-0.46	31.97	25.70
6.5	-0.49	31.97	25.71
8.5	-0.50	31.98	25.71

CAST 35 LOCATION Station 1
DATE 30 IX 59 GMT 1735
DEPTH 10 M

Depth M	T °C	S ‰	σ_t
0.0	-0.55	32.15	25.85
3.5	-0.53	32.15	25.85
6.5	-0.54	32.15	25.85
9.5	-0.54	32.15	25.85

CAST 36 LOCATION Station 1
DATE 1 X 59 GMT 1640
DEPTH 11 M

Depth M	T °C	S ‰	σ_t
0.0	-0.33	32.30	25.97
3.5	-0.32	32.30	25.97
5.5	-0.32	32.30	25.97
8.5	-0.34	32.30	25.97
10.5	-0.34	32.30	25.97

CAST 37 LOCATION Station 2
DATE 2 X 59 GMT 1200
DEPTH 27 M

Depth M	T °C	S ‰	σ_t
0	-0.48	32.31	25.98
6	-0.42	32.32	25.99
15	-0.40	32.33	25.99
22	-0.42	32.33	25.99
26	-0.42	32.35	26.01

CAST 38 LOCATION Station 3
DATE 2 X 59 GMT 1250
DEPTH 38 M

Depth M	T °C	S ‰	σ_t
0	-0.51	32.29	25.96
5	-0.51	32.29	25.96
19	-0.40	32.33	25.99
33	-0.26	32.35	26.16
37	-0.26	32.73	26.31

CAST 39 LOCATION Station 4
DATE 2 X 59 GMT 1326
DEPTH 37 M

Depth M	T °C	S ‰	σ_t
0	-0.54	32.28	25.96
7	-0.54	32.30	25.97
18	-0.42	32.33	25.99
30	-0.26	32.55	26.16
36	-0.26	32.73	26.31

CAST 40 LOCATION Station 1*
DATE 2 X 59 GMT 1600
DEPTH 11 M

Depth M	T °C	S ‰	σ_t
0.0	-0.45	32.30	25.97
3.5	-0.44	32.30	25.97
7.5	-0.46	32.30	25.97
10.5	-0.46	32.30	25.97

CAST 41 LOCATION Station 1*
DATE 3 X 59 GMT 1300
DEPTH 9.5 M

Depth M	T °C	S ‰	σ_t
0.0	-0.55	32.30	25.97
3.5	-0.55	32.30	25.97
7.0	-0.56	32.30	25.97
9.0	-0.56	32.30	25.97

* Bubbling system in operation

CAST 42 LOCATION Station 1*
DATE 4 X 59 GMT 1355
DEPTH 11 M

Depth M	T °C	S ‰	σ_t
0.0	-0.56	32.25	25.93
3.5	-0.56	32.25	25.93
7.5	-0.56	32.25	25.93
10.5	-0.54	32.29	25.97

CAST 43 LOCATION Station 2
DATE 5 X 59 GMT 1152
DEPTH 27 M

Depth M	T °C	S ‰	σ_t
0	-0.73	32.28	25.96
6	-0.73	32.28	25.96
16	-0.68	32.28	25.96
22	-0.68	32.28	25.96
26	-0.70	32.28	25.96

CAST 44 LOCATION Station 3
DATE 5 X 59 GMT 1236
DEPTH 39 M

Depth M	T °C	S ‰	σ_t
0	-0.71	32.28	25.96
6	-0.71	32.28	25.96
20	-0.65	32.28	25.96
34	-0.43	32.55	26.17
38	-0.31	32.65	26.25

* Bubbling system in operation

CAST 45 LOCATION Station 4
DATE 5 X 59 GMT 1337
DEPTH 37 M

Depth M	T °C	S ‰	σ_t
0	-0.69	32.26	25.95
6	-0.70	32.27	25.96
20	-0.65	32.29	25.97
33	-0.46	32.49	26.12
37	-0.37	32.60	26.21

CAST 46 LOCATION Station 1*
DATE 5 X 59 GMT 1715
DEPTH 11 M

Depth M	T °C	S ‰	σ_t
0.0	-0.69	32.28	25.96
3.5	-0.69	32.28	25.96
7.5	-0.69	32.29	25.97
10.5	-0.69	32.31	25.99

CAST 47 LOCATION Station 1
DATE 6 X 59 GMT 1640
DEPTH 10.5 M

Depth M	T °C	S ‰	σ_t
0	-1.07	32.26	25.96
3	-0.85	32.27	25.96
7	-0.89	32.28	25.97
10	-0.82	32.34	26.02

CAST 48 LOCATION Station 1
DATE 7 X 59 GMT 1141
DEPTH 9.5 M

Depth M	T °C	S ‰	σ_t
0	-1.02	———	———
3	-0.98	———	———
6	-1.02	———	———
9	-1.04	———	———

CAST 49 LOCATION Station 1
DATE 8 X 59 GMT 1400
DEPTH 9 M

Depth M	T °C	S ‰	σ_t
0.0	-1.24	32.27	25.97
3.5	-1.21	32.28	25.98
6.5	-1.21	32.28	25.98
8.5	-1.18	32.28	25.98

CAST 50 LOCATION Station 2
DATE 8 X 59 GMT 1800
DEPTH 26 M

Depth M	T °C	S ‰	σ_t
0	-1.02	32.32	26.01
10	-0.81	32.45	26.10
21	-0.53	32.61	26.22
25	-0.49	32.70	26.29

CAST 51 LOCATION Station 4
DATE 8 X 59 GMT 1835
DEPTH 37 M

Depth M	T °C	S ‰	σ_t
0	-1.08	32.29	25.98
10	-1.03	32.31	26.00
20	-0.63	32.62	26.24
33	-0.53	32.74	26.33
37	-0.51	32.82	26.39

CAST 52 LOCATION Station 3
DATE 8 X 59 GMT 1917
DEPTH 39 M

Depth M	T °C	S ‰	σ_t
0	-1.04	32.30	25.99
10	-1.02	32.32	26.01
20	-0.82	32.41	26.07
33	-0.49	32.78	26.36
37	-0.52	32.89	26.45

CAST 53 LOCATION Station 1
DATE 9 X 59 GMT 1200
DEPTH 9 M

Depth M	T °C	S ‰	σ_t
0.0	-0.96	———	———
3.5	-0.96	———	———
6.5	-0.96	———	———
8.5	-0.96	———	———

CAST 54 LOCATION Station 1*
DATE 10 X 59 GMT 1206
DEPTH 10 M

Depth M	T °C	S ‰	σ_t
0.0	-0.94	32.36	26.04
3.5	-0.91	32.36	26.03
7.5	-0.92	32.36	26.03
9.5	-0.92	32.43	26.09

CAST 55 LOCATION Station 1*
DATE 11 X 59 GMT 1410
DEPTH 10 M

Depth M	T °C	S ‰	σ_t
0.0	-0.90	32.42	26.08
3.5	-0.91	32.42	26.08
6.5	-0.91	32.42	26.08
9.5	-0.89	32.43	26.09

CAST 56 LOCATION Station 2
DATE 12 X 59 GMT 1305
DEPTH 24 M

Depth M	T °C	S ‰	σ_t
0	-1.42	32.32	26.02
5	-1.40	32.32	26.02
15	-1.42	32.32	26.02
22	-0.69	32.52	26.16
24	-0.78	32.52	26.16

* Bubbling system in operation

CAST 57 LOCATION Station 3
DATE 12 X 59 GMT 1405
DEPTH 36 M

Depth M	T °C	S ‰	σ_t
0	-1.32	32.34	26.03
5	-1.39	32.34	26.03
18	-0.96	32.39	26.06
29	-0.64	32.59	26.21
33	-0.62	32.65	26.26

CAST 58 LOCATION Station 4
DATE 12 X 59 GMT 1505
DEPTH 36 M

Depth M	T °C	S ‰	σ_t
0	———	32.34	———
7	-1.28	32.36	26.05
20	-1.10	32.39	26.06
31	-0.60	32.63	26.24
35	-0.56	32.67	26.27

CAST 59 LOCATION Station 1
DATE 12 X 59 GMT 1820
DEPTH 9 M

Depth M	T °C	S ‰	σ_t
0.0	-1.31	———	———
2.5	-1.28	———	———
5.5	-1.26	———	———
8.5	-1.25	———	———

CAST 60 LOCATION Station 1*
DATE 13 X 59 GMT 1310
DEPTH 10 M

Depth M	T °C	S ‰	σ_t
0.0	-1.09	—	—
3.5	-1.08	—	—
6.5	-1.06	—	—
9.5	-1.06	—	—

CAST 61 LOCATION Station 1D
DATE 13 X 59 GMT 1420
DEPTH 9.5 M

Depth M	T °C	S ‰	σ_t
0	-1.76	—	—
3	-1.60	—	—
6	-1.25	—	—
9	-1.24	—	—

CAST 62 LOCATION Station 1*
DATE 14 X 59 GMT 1315
DEPTH 10 M

Depth M	T °C	S ‰	σ_t
0.0	-1.25	—	—
3.5	-1.26	—	—
6.5	-1.17	—	—
9.5	-1.18	—	—

CAST 63 LOCATION Station 1*
DATE 15 X 59 GMT 1710
DEPTH 10 M

Depth M	T °C	S ‰	σ_t
0	-1.54	—	—

CAST 64 LOCATION Station 1
DATE 17 X 59 GMT 1720
DEPTH 10 M

Depth M	T °C	S ‰	σ_t
0.5	-1.67	—	—
3.5	-1.66	—	—
9.5	-1.58	—	—

CAST 65 LOCATION Station 1*
DATE 18 X 59 GMT 1710
DEPTH 11 M

Depth M	T °C	S ‰	σ_t
0.0	-1.66	—	—
4.5	-1.64	—	—
7.5	-1.63	—	—
10.5	-1.64	—	—

* Bubbling system in operation

CAST 66 LOCATION Station 1*
DATE 19 X 59 GMT 1430
DEPTH 10 M

Depth M	T °C	S ‰	σ_t
0.0	-1.69	—	—
3.5	-1.67	—	—
6.5	-1.66	—	—
9.5	-1.55	—	—
10.5**	-1.53	—	—

CAST 67 LOCATION Station 1*
DATE 20 X 59 GMT 1650
DEPTH 10.5 M

Depth M	T °C	S ‰	σ_t
0	-1.76	—	—
4	-1.75	—	—
8	-1.73	—	—
10	-1.66	—	—

* Bubbling system in operation

** Sample obtained at 1805Z - bubbling system in operation

CAST 68 LOCATION Station 1*
DATE 21 X 59 GMT 1500
DEPTH 9.5 M

Depth M	T °C	S ‰	σ_t
0	-1.66	—	—
3	-1.67	—	—
7	-1.66	—	—
9	-1.66	—	—

CAST 69 LOCATION Station 1*
DATE 18 IV 60 GMT 1710
DEPTH 13 M

Depth M	T °C	S ‰	σ_t
0	-1.83	—	—
6	-1.83	—	—
12	-1.83	—	—

CAST 70 LOCATION Station 2
DATE 26 IV 60 GMT 1730
DEPTH ____

Depth M	T °C	S ‰	σ_t
0	-1.82	—	—
12	-1.82	—	—
24	-1.82	—	—

APPENDIX IV

OCEANOGRAPHIC DATA

OUTER STATIONS, 1959

APPENDIX IV - OCEANOGRAPHIC DATA (OUTER STATIONS), 1959

CAST 1 LOCATION Station 6
DATE 15 IX 59 GMT 1600
DEPTH 41 M

Depth M	T °C	S ‰	σ_t
0	1.03	30.98	24.85
5	0.96	30.98	24.85
10	1.08	31.10	24.93
15	1.09	31.45	25.21
20	1.04	31.72	25.44
25	0.84	31.91	25.61
30	0.45	32.51	26.10
35	0.32	32.63	26.21
40	0.26	32.72	26.28

CAST 3 LOCATION Station 8
DATE 15 IX 59 GMT 1900
DEPTH 16 M

Depth M	T °C	S ‰	σ_t
0	1.09	31.14	24.96
5	1.04	31.18	25.01
10	1.12	31.31	25.10
15	0.87	31.92	25.60

CAST 2 LOCATION Station 7
DATE 15 IX 59 GMT 1800
DEPTH 35 M

Depth M	T °C	S ‰	σ_t
0	1.04	30.99	24.86
5	1.03	31.20	25.02
10	1.07	31.42	25.19
15	0.93	31.74	25.46
20	0.76	32.06	25.73
25	0.64	32.27	25.90
30	0.42	32.52	26.11
35	0.29	32.67	26.24

CAST 4 LOCATION Station 9
DATE 15 IX 59 GMT 2000
DEPTH 16 M

Depth M	T °C	S ‰	σ_t
0	1.01	31.01	24.87
5	1.01	31.13	24.97
10	1.11	31.37	25.15
15	0.79	32.01	25.69

CAST 5 LOCATION Station 6
DATE 21 IX 59 GMT 1100
DEPTH 35 M

Depth M	T °C	S °/oo	σ_t
0	0.42	31.58	25.35
5	0.57	31.58	25.35
10	0.53	32.00	25.69
15	0.53	32.17	25.83
20	0.47	32.27	25.91
25	0.44	32.30	25.93
30	0.34	32.40	26.02
35	0.21	32.60	26.18

CAST 6 LOCATION Station 7
DATE 21 IX 59 GMT 1200
DEPTH 33 M

Depth M	T °C	S °/oo	σ_t
0	0.42	31.63	25.39
5	0.42	31.69	25.44
10	0.49	31.77	25.50
15	0.54	32.29	25.92
20	0.39	32.45	25.98
25	0.25	32.54	26.13
30	0.23	32.59	26.17

CAST 7 LOCATION Station 8
DATE 21 IX 59 GMT 1300
DEPTH 17 M

Depth M	T °C	S °/oo	σ_t
0	0.39	31.54	25.33
5	0.39	31.55	25.34
10	0.48	31.95	25.65
15	0.48	32.20	25.85

CAST 8 LOCATION Station 9
DATE 21 IX 59 GMT 1400
DEPTH 17 M

Depth M	T °C	S °/oo	σ_t
0	0.29	31.47	25.27
5	0.31	31.47	25.27
10	0.50	31.76	25.50
15	0.48	32.18	25.83

CAST 9 LOCATION Station 6
DATE 28 IX 59 GMT 1100
DEPTH 38 M

Depth M	T °C	S °/oo	σ_t
0	-0.48	31.90	25.66
5	-0.46	32.00	25.74
10	-0.44	32.18	25.88
15	-0.34	32.28	25.95
20	-0.28	32.31	25.97
25	-0.24	32.46	26.10
30	-0.21	32.62	26.22
35	-0.19	32.77	26.35

CAST 10 LOCATION Station 7
DATE 28 IX 59 GMT 1200
DEPTH 33 M

Depth M	T °C	S °/oo	σ_t
0	-0.49	31.97	25.71
5	-0.43	32.06	25.79
10	-0.27	32.28	25.95
15	-0.27	32.37	26.02
20	-0.27	32.37	26.02
25	-0.26	32.39	26.04
30	-0.18	32.54	26.16

CAST 11 LOCATION Station 8
DATE 28 IX 59 GMT 1300
DEPTH 17 M

Depth M	T °C	S °/oo	σ_t
0	-0.62	31.74	25.53
5	-0.47	31.89	25.65
10	-0.22	32.27	25.94
15	-0.24	32.34	26.00

CAST 12 LOCATION Station 9
DATE 28 IX 59 GMT 1400
DEPTH 17 M

Depth M	T °C	S °/oo	σ_t
0	-0.52	31.85	25.62
5	-0.31	32.10	25.80
10	-0.32	32.26	25.93
15	-0.13	32.35	26.01

CAST 13 LOCATION Station 6
DATE 5 X 59 GMT 1100
DEPTH 41 M

Depth M	T °C	S °/oo	σ_t
0	-0.60	32.26	25.95
5	-0.59	32.26	25.95
10	-0.58	32.28	25.96
15	-0.57	32.28	25.96
20	-0.56	32.33	26.00
25	-0.52	32.46	26.11
30	-0.48	32.50	26.14
35	-0.50	32.66	26.27
40	-0.54	32.68	26.29

CAST 14 LOCATION Station 7
DATE 5 X 59 GMT 1200
DEPTH 35 M

Depth M	T °C	S °/oo	σ_t
0	-0.60	32.26	25.95
5	-0.59	32.26	25.95
10	-0.58	32.28	25.96
15	-0.58	32.29	25.97
20	-0.55	32.32	26.00
25	-0.55	32.39	26.05
30	-0.48	32.47	26.12

CAST 15 LOCATION Station 8
DATE 5 X 59 GMT 1300
DEPTH 16 M

Depth M	T °C	S °/oo	σ_t
0	-0.62	32.25	25.94
5	-0.61	32.28	25.96
10	-0.55	32.28	25.96
15	-0.57	32.28	25.96

CAST 16 LOCATION Station 9
DATE 5 X 59 GMT 1400
DEPTH 20 M

Depth M	T °C	S °/oo	σ_t
0	-0.67	32.27	25.96
5	-0.65	32.28	25.96
10	-0.66	32.28	25.96
15	-0.62	32.30	25.98

CAST 17
DATE 12 X 59
DEPTH 16 M
LOCATION Station 9
GMT 1300

Depth M	T °C	S °/oo	σ_t
0	-1.17	32.38	26.07
5	-1.18	32.38	26.07
10	-1.15	32.38	26.07
15	-1.10	32.40	26.07

CAST 18
DATE 12 X 59
DEPTH 18 M
LOCATION Station 8
GMT 1400

Depth M	T °C	S °/oo	σ_t
0	-1.16	32.38	26.07
5	-1.15	32.38	26.07
10	-0.94	32.44	26.11
15	-0.87	32.49	26.15

CAST 19
DATE 12 X 59
DEPTH 27 M
LOCATION Station 7
GMT 1500

Depth M	T °C	S °/oo	σ_t
0	-1.13	32.38	26.06
5	-1.14	32.39	26.08
10	-1.08	32.41	26.08
15	-0.90	32.44	26.11
20	-0.86	32.48	26.14
25	-0.87	32.49	26.15

CAST 20
DATE 12 X 59
DEPTH 45 M
LOCATION Station 6
GMT 1600

Depth M	T °C	S °/oo	σ_t
0	-1.16	32.37	26.05
5	-1.13	32.39	26.07
10	-1.00	—	—
15	-0.94	—	—
20	-0.89	—	—
25	-0.79	—	—
30	-0.74	—	—
35	-0.74	—	—

APPENDIX V

SYNOPTIC METEOROLOGICAL OBSERVATIONS

THULE AIR BASE - 1959

APPENDIX V - SYNOPTIC METEOROLOGICAL OBSERVATIONS, 1959

Date	Time (local)	Air Temperature Dry (°F)	Air Temperature Wet (°F)	Wind Speed (knots)	Wind Dir. (°T)	Date	Time (local)	Air Temperature Dry (°F)	Air Temperature Wet (°F)	Wind Speed (knots)	Wind Dir. (°T)
September						September					
1	0258	29.8	28.0	4	ENE	4	0258	31.5	29.1	Calm	
	0556	30.0	28.0	6	E		0556	31.5	29.0	2	E
	0856	34.9	29.9	11	SE		0858	32.3	29.3	3	E
	1156	36.8	31.9	16	SE		1156	35.7	31.6	Calm	
	1459	39.3	34.0	15	SE		1459	36.6	32.2	Calm	
	1755	37.3	32.8	10	SE		1755	36.8	32.0	5	WNW
	2055	35.4	32.1	14	SE		2056	33.6	31.0	Calm	
	2355	34.6	31.9	8	SSE		2355	29.9	27.1	4	ESE
2	0258	33.4	31.4	6	NE	5	0255	28.1	25.5	2	E
	0555	31.4	30.5	Calm			0555	28.7	27.0	4	E
	0856	33.1	31.2	6	W		0856	29.8	26.9	5	E
	1156	36.5	31.3	3	WSW		1156	32.1	28.0	2	E
	1459	36.9	31.9	6	NNW		1459	34.2	29.8	4	W
	1755	37.4	32.0	8	W		1755	34.6	30.0	4	W
	2055	34.8	29.9	2	NE		2055	32.5	29.1	Calm	
	2355	29.4	26.8	7	ESE		2355	26.8	24.7	3	SE
3	0257	26.8	25.0	8	E	6	0257	28.0	26.1	4	E
	0555	26.2	24.1	8	E		0556	27.1	24.9	4	ESE
	0856	29.8	27.1	10	SE		0858	29.4	25.8	5	E
	1156	32.7	29.7	11	SE		1158	32.1	28.1	12	SSE
	1456	32.9	29.7	19	SE		1458	31.9	28.1	16	SSE
	1758	32.8	29.2	14	SE		1756	32.0	28.1	10	ESE
	2058	32.0	28.9	12	SE		2059	30.8	27.8	13	SE
	2356	32.0	29.2	Calm			2356	31.7	28.1	13	ESE

APPENDIX V - SYNOPTIC METEOROLOGICAL OBSERVATIONS, 1959

Date	Time (local)	Air Temperature Dry (°F)	Air Temperature Wet (°F)	Wind Speed (knots)	Wind Dir. (°T)	Date	Time (local)	Air Temperature Dry (°F)	Air Temperature Wet (°F)	Wind Speed (knots)	Wind Dir. (°T)
September						September					
7	0257	32.0	30.0	15	SE	10	0255	29.5	26.5	4	E
	0555	31.4	29.3	10	E		0555	29.0	26.1	4	E
	0856	32.3	30.1	5	ESE		0856	30.3	27.1	4	ESE
	1156	33.9	31.0	10	SSE		1155	36.4	29.1	4	ENE
	1456	34.6	30.8	17	SSE		1456	36.4	30.2	Calm	
	1759	35.8	30.2	4	ENE		1755	37.8	30.9	5	E
	2055	30.6	27.9	Calm			2055	34.3	30.1	4	SSE
	2355	26.2	24.7	Calm			2355	32.4	29.6	Calm	
8	0255	24.2	22.4	4	ENE	11	0258	31.8	29.4	11	NE
	0555	22.9	20.8	6	E		0556	31.9	31.0	Calm	
	0856	26.4	23.7	1	E		0856	34.2	32.1	8	NE
	1158	33.4	27.8	Calm			1156	37.0	33.2	15	ENE
	1456	35.1	29.6	3	WSW		1457	37.0	33.1	9	NE
	1755	36.0	31.4	2	WSW		1755	35.4	32.8	4	WSW
	2055	32.4	28.7	3	E		2055	34.6	32.1	Calm	
	2355	28.2	25.8	6	E		2355	32.4	29.1	4	ENE
9	0257	25.9	22.9	8	E	12	0255	28.1	25.9	4	E
	0555	25.4	22.6	6	E		0555	28.9	26.3	5	E
	0856	29.6	25.3	6	E		0856	33.7	30.4	7	E
	1156	37.1	30.9	2	WSW		1156	36.1	32.1	2	ESE
	1456	35.4	29.9	2	WSW		1456	38.0	34.0	3	NE
	1756	34.9	29.5	Calm			1758	37.1	33.2	10	ESE
	2058	32.3	27.8	3	ENE		2056	35.8	31.9	6	E
	2357	30.2	26.3	4	E		2356	36.0	33.9	Calm	

APPENDIX V - SYNOPTIC METEOROLOGICAL OBSERVATIONS, 1959

Date	Time (local)	Air Temperature Dry (°F)	Air Temperature Wet (°F)	Wind Speed (knots)	Wind Dir. (°T)	Date	Time (local)	Air Temperature Dry (°F)	Air Temperature Wet (°F)	Wind Speed (knots)	Wind Dir. (°T)
September						September					
13	0256	33.8	31.0	8	ENE	16	0255	28.8	24.8	8	ESE
	0556	34.0	32.0	Calm			0555	25.0	22.0	8	E
	0856	33.6	31.5	3	N		0856	23.9	21.0	7	E
	1156	34.9	31.8	3	E		1156	32.2	27.1	Calm	
	1456	36.9	32.2	11	E		1456	34.8	28.6	2	E
	1755	35.4	31.8	7	NE		1755	34.4	28.5	6	SSE
	2055	35.4	31.7	4	E		2055	28.9	26.0	Calm	
	2355	33.1	30.7	3	E		2355	24.9	22.4	3	ENE
14	0255	32.9	30.5	Calm		17	0255	29.2	26.8	14	SE
	0559	31.6	29.5	Calm			0555	30.3	27.4	14	ESE
	0858	31.9	29.4	8	SSE		0856	31.5	30.1	12	SE
	1156	35.1	31.1	6	ESE		1156	31.1	28.9	12	ESE
	1456	34.8	31.9	10	ESE		1457	31.3	29.8	16	SE
	1755	33.4	30.5	10	SE		1755	31.2	29.2	4	E
	2055	32.4	29.6	8	ENE		2055	29.7	28.8	6	NE
	2355	31.0	29.1	9	W		2355	30.2	28.6	2	E
15	0255	31.1	29.6	2	ESE	18	0259	29.1	28.6	Calm	
	0555	27.9	26.3	5	ENE		0555	29.6	29.0	Calm	
	0856	28.4	26.4	4	ESE		0859	29.6	28.4	Calm	
	1156	31.2	28.2	Calm			1159	30.4	29.3	Calm	
	1456	33.1	30.1	2	W		1459	30.6	29.7	Calm	
	1757	33.8	31.1	Calm			1757	30.4	29.1	2	N
	2058	30.2	26.7	Calm			2058	28.8	27.9	Calm	
	2359	29.1	25.0	4	SSE		2358	28.8	28.2	Calm	

APPENDIX V - SYNOPTIC METEOROLOGICAL OBSERVATIONS, 1959

Date	Time (local)	Air Temperature Dry (°F)	Air Temperature Wet (°F)	Wind Speed (knots)	Wind Dir. (°T)
September					
19	0255	28.1	27.6	Calm	
	0559	30.1	29.4	2	SW
	0858	29.2	23.9	Calm	
	1156	28.6	28.0	4	E
	1456	29.8	27.9	3	ESE
	1755	27.9	27.5	4	ESE
	2055	21.2	19.9	6	E
	2355	22.1	20.7	6	E
20	0255	23.1	21.3	12	NE
	0555	20.9	19.1	5	E
	0856	25.4	23.8	4	E
	1156	25.4	23.3	3	E
	1456	27.6	26.1	3	ESE
	1758	29.3	27.4	Calm	
	2055	27.6	25.8	Calm	
	2355	26.2	24.2	Calm	
21	0257	18.7	17.6	6	E
	0555	21.6	20.4	6	E
	0855	15.4	14.2	5	ENE
	1159	21.3	19.6	5	E
	1455	21.1	20.1	4	E
	1756	22.7	20.8	4	E
	2056	16.8	16.0	9	E
	2356	15.6	14.9	7	E

Date	Time (local)	Air Temperature Dry (°F)	Air Temperature Wet (°F)	Wind Speed (knots)	Wind Dir. (°T)
September					
22	0255	21.5	20.6	10	SE
	0555	27.0	25.6	8	SSW
	0856	25.1	23.1	6	NE
	1156	23.4	21.9	5	SW
	1458	23.8	21.8	4	WSW
	1756	23.7	21.9	4	W
	2055	23.0	21.8	6	W
	2355	23.4	22.0	4	WNW
23	0255	24.0	22.4	8	W
	0555	25.1	23.2	6	W
	0856	23.4	21.9	4	ENE
	1159	23.8	21.6	4	NE
	1459	23.2	22.2	6	SW
	1759	23.4	22.4	4	W
	2055	23.4	22.0	3	WNW
	2355	23.6	22.1	4	W
24	0255	24.0	22.5	4	WNW
	0559	23.8	22.4	5	WNW
	0859	21.3	19.9	5	ESE
	1159	21.8	20.3	9	E
	1455	20.8	19.9	6	E
	1756	20.8	19.0	4	ESE
	2056	17.0	15.7	7	ESE
	2356	24.8	23.Q	10	ESE

APPENDIX V - SYNOPTIC METEOROLOGICAL OBSERVATIONS, 1959

Date	Time (local)	Air Temperature Dry (°F)	Air Temperature Wet (°F)	Wind Speed (knots)	Wind Dir. (°T)	Date	Time (local)	Air Temperature Dry (°F)	Air Temperature Wet (°F)	Wind Speed (knots)	Wind Dir. (°T)
September						September					
25	0255	26.0	24.5	20	E	28	0259	23.4	22.4	5	SSE
	0555	27.4	25.8	20	E		0559	23.4	21.3	8	S
	0859	25.6	24.7	11	ESE		0859	23.1	21.6	2	SSE
	1157	27.9	25.3	17	ESE		1159	22.2	21.4	6	SSW
	1456	28.4	25.7	10	ESE		1458	20.6	19.4	8	SE
	1755	27.4	25.3	13	ESE		1755	19.2	18.0	10	SE
	2055	25.6	23.4	14	ESE		2055	19.1	17.9	6	ESE
	2355	25.7	23.6	8	E		2355	23.9	22.7	7	SE
26	0255	24.8	23.0	4	E	29	0259	26.0	24.4	4	NNE
	0555	22.0	20.7	5	E		0559	26.0	24.4	20	ESE
	0856	17.6	16.7	8	E		0857	25.4	24.8	5	SSE
	1159	22.9	20.9	6	E		1159	24.9	23.1	8	SSE
	1456	23.3	21.4	5	ESE		1459	24.2	22.0	Calm	
	1755	22.2	20.0	5	ESE		1758	22.9	22.0	2	SSW
	2055	16.3	15.0	5	E		2055	30.0	27.8	14	ESE
	2355	14.3	13.4	5	E		2355	29.0	26.8	16	E
27	0255	13.1	12.3	6	E	30	0255	30.1	28.4	6	ENE
	0557	13.4	12.5	5	E		0557	29.1	28.1	12	E
	0856	13.9	12.8	6	E		0859	31.2	29.7	10	E
	1156	20.3	19.4	2	NNW		1159	33.4	31.4	23	E
	1456	24.1	22.1	Calm			1459	33.4	32.1	18	ENE
	1759	22.9	21.1	8	SW		1758	35.1	33.6	18	E
	2057	22.8	21.1	6	S		2059	33.4	31.8	18	E
	2355	24.3	23.0	3	SE		2359	34.2	32.3	24	ESE

APPENDIX V - SYNOPTIC METEOROLOGICAL OBSERVATIONS, 1959

Date	Time (local)	Air Temperature Dry (°F)	Air Temperature Wet (°F)	Wind Speed (knots)	Wind Dir. (°T)	Date	Time (local)	Air Temperature Dry (°F)	Air Temperature Wet (°F)	Wind Speed (knots)	Wind Dir. (°T)
October						October					
1	0255	33.4	31.3	23	ESE	4	0255	30.0	28.5	5	ENE
	0555	34.1	31.9	16	E		0555	30.3	28.2	6	E
	0856	29.8	27.4	15	NE		0856	25.1	23.5	4	ENE
	1158	34.9	32.4	12	E		1157	27.8	26.0	Calm	
	1456	34.3	32.0	18	E		1458	31.1	29.3	2	SW
	1755	36.1	31.9	8	E		1755	26.8	25.7	4	ENE
	2055	35.3	31.9	8	SW		2056	19.1	18.0	4	E
	2355	32.0	30.0	4	E		2355	18.0	16.8	6	ENE
2	0255	30.1	27.9	6	ESE	5	0255	17.0	16.0	8	E
	0555	25.6	23.5	8	E		0555	19.8	18.0	9	E
	0859	23.3	21.5	6	ENE		0856	19.9	18.4	8	E
	1159	24.2	21.9	6	ENE		1156	24.6	22.3	5	ENE
	1456	27.6	25.1	Calm			1456	23.4	21.4	4	E
	1755	27.0	24.5	8	E		1755	22.6	20.3	4	E
	2055	25.5	23.8	8	E		2053	17.3	16.0	6	ENE
	2355	24.2	22.0	9	E		2355	16.4	15.4	4	ENE
3	0257	25.8	24.2	7	E	6	0255	15.0	14.1	7	E
	0555	31.9	27.4	8	E		0555	15.0	13.9	7	ENE
	0859	24.2	22.3	5	E		0856	16.8	15.3	5	E
	1158	25.8	23.7	4	ENE		1155	20.9	18.7	7	ENE
	1458	26.4	24.8	8	ENE		1457	23.1	20.8	6	E
	1756	33.4	30.0	14	SE		1756	18.2	16.6	6	E
	2057	33.1	30.0	8	ESE		2056	13.2	12.1	6	E
	2356	32.0	31.1	4	SSE		2356	15.1	13.8	8	E

APPENDIX V - SYNOPTIC METEOROLOGICAL OBSERVATIONS, 1959

Date	Time (local)	Air Temperature Dry (°F)	Air Temperature Wet (°F)	Wind Speed (knots)	Wind Dir. (°T)	Date	Time (local)	Air Temperature Dry (°F)	Air Temperature Wet (°F)	Wind Speed (knots)	Wind Dir. (°T)
October						October					
7	0255	15.4	14.0	8	E	10	0256	21.9	19.5	Calm	
	0555	12.6	11.4	6	E		0556	16.5	14.2	4	ENE
	0857	15.9	14.6	4	ENE		0856	19.2	18.1	4	E
	1157	18.1	16.3	2	ENE		1156	19.3	16.2	7	ENE
	1456	18.7	17.1	3	ENE		1456	20.9	19.4	1	E
	1755	16.0	15.1	6	ENE		1755	22.4	21.3	Calm	
	2055	13.8	12.9	5	ENE		2055	22.8	21.9	Calm	
	2355	15.6	14.4	6	E		2355	22.3	21.2	Calm	
8	0255	16.8	15.6	3	NE	11	0257	23.0	22.6	Calm	
	0555	28.8	26.7	20	SSE		0557	24.0	23.5	Calm	
	0856	31.1	29.1	8	NE		0859	24.2	23.3	Calm	
	1156	31.4	29.2	20	SE		1159	24.6	23.3	2	N
	1455	33.4	30.6	10	E		1459	23.4	21.8	4	E
	1755	33.2	30.2	15	E		1757	23.2	22.0	8	SE
	2058	34.2	31.0	Calm			2055	20.0	18.9	4	ENE
	2355	33.5	31.0	4	E		2355	20.0	19.1	Calm	
9	0257	30.9	28.8	8	SE	12	0256	21.3	20.7	6	W
	0556	27.6	26.5	8	ESE		0556	21.3	20.7	7	W
	0859	25.8	24.4	Calm			0859	19.6	18.3	6	WSW
	1158	24.9	23.3	Calm			1159	19.7	18.6	4	W
	1455	25.9	24.1	4	WSW		1459	16.9	15.6	4	ENE
	1758	25.0	24.1	8	WNW		1756	17.8	16.9	Calm	
	2056	25.1	24.0	8	WNW		2056	18.3	16.9	8	N
	2358	24.2	22.8	4	WNW		2356	17.8	16.2	12	WNW

APPENDIX V - SYNOPTIC METEOROLOGICAL OBSERVATIONS, 1959

Date	Time (local)	Air Temperature Dry (°F)	Air Temperature Wet (°F)	Wind Speed (knots)	Wind Dir. (°T)	Date	Time (local)	Air Temperature Dry (°F)	Air Temperature Wet (°F)	Wind Speed (knots)	Wind Dir. (°T)
October						October					
13	0258	16.3	14.9	2	WNW	16	0258	7.8	7.2	7	ESE
	0558	15.0	13.9	5	E		0557	8.0	7.4	6	E
	0856	15.7	14.2	4	ESE		0859	6.7	6.1	8	E
	1156	15.4	14.0	2	ENE		1159	2.7	2.2	9	E
	1459	15.4	14.6	1	E		1459	8.2	7.5	6	E
	1755	15.1	14.6	2	E		1756	13.2	12.1	11	ENE
	2055	0.1	-0.2	6	E		2057	14.9	13.4	6	E
	2355	-1.6	-1.9	8	E		2356	12.2	11.4	6	E
14	0256	1.9	1.2	6	ENE	17	0255	0.2	-0.1	4	ENE
	0555	-1.6	-2.1	10	E		0555	0.0	-0.5	6	E
	0856	-1.3	-1.8	10	E		0856	-2.1	-2.5	5	E
	1156	-3.2	-3.7	11	E		1157	4.3	3.7	5	ESE
	1456	2.1	1.5	10	E		1459	-2.2	-3.3	7	E
	1755	-0.6	-1.0	10	E		1755	-1.7	-2.1	8	E
	2055	-1.6	-2.1	12	E		2055	-2.3	-2.6	8	E
	2355	-3.7	-4.2	10	E		2355	-4.5	-4.8	9	E
15	0256	-4.1	-4.6	9	E	18	0255	-2.6	-3.0	7	ENE
	0555	-4.1	-4.6	6	E		0556	-6.2	-6.7	10	E
	0856	-6.4	-6.8	9	E		0856	-2.8	-3.4	8	E
	1156	-4.9	-5.3	10	E		1156	-4.3	-4.8	10	E
	1456	-3.6	-4.1	9	ESE		1456	-4.1	-4.6	10	E
	1756	-6.0	-6.3	8	E		1755	-4.1	-4.6	10	E
	2056	-7.1	-7.3	8	E		2056	-2.7	-3.2	10	E
	2356	-5.9	-6.2	10	E		2355	-1.7	-2.3	10	E

APPENDIX V - SYNOPTIC METEOROLOGICAL OBSERVATIONS, 1959

Date	Time (local)	Air Temperature Dry (°F)	Air Temperature Wet (°F)	Wind Speed (knots)	Wind Dir. (°T)	Date	Time (local)	Air Temperature Dry (°F)	Air Temperature Wet (°F)	Wind Speed (knots)	Wind Dir. (°T)
October						October					
19	0257	6.0	5.3	7	ENE	22	0257	-3.2	-3.5	8	E
	0555	12.3	10.9	Calm			0558	-3.6	-3.8	8	E
	0856	13.8	12.8	5	E		0858	-2.1	-3.8	9	E
	1156	14.1	13.0	4	WNW		1156	3.1	1.5	8	E
	1456	11.0	8.1	Calm			1456	2.9	2.1	4	ENE
	1755	10.8	9.7	6	SE		1755	2.6	1.9	6	E
	2055	11.2	10.0	4	E		2055	8.4	7.6	5	E
	2355	12.1	11.3	4	E		2355	11.4	10.2	5	ENE
20	0255	11.5	10.7	3	E	23	0255	11.5	10.3	2	E
	0555	12.0	11.0	4	ENE		0555	13.6	12.3	2	E
	0857	9.3	8.1	2	ENE		0856	13.4	12.1	3	E
	1158	4.4	3.1	6	E		1155	14.9	13.7	6	E
	1456	8.1	7.6	8	E		1455	16.0	15.1	Calm	
	1755	-1.5	-1.9	6	E		1755	18.2	17.3	3	SSW
	2055	-7.5	-7.6	6	ENE		2057	22.5	21.8	3	SSW
	2355	-8.5	-8.6	12	E		2355	21.4	20.5	4	NE
21	0255	-12.1	-12.3	7	ENE	24	0256	21.6	20.0	8	SSE
	0555	-9.6	-9.9	6	ENE		0555	20.9	19.4	8	SSE
	0855	-11.0	-11.3	11	ENE		0856	19.7	18.3	7	SE
	1156	-6.4	-6.8	8	E		1158	17.6	16.6	12	SSE
	1456	-4.2	-4.7	6	E		1459	16.9	15.8	12	SSE
	1756	-3.7	-4.2	4	E		1756	14.2	13.1	4	E
	2056	-2.2	-3.3	6	E		2056	6.9	4.5	4	ENE
	2356	-3.2	-3.5	10	E		2356	11.8	11.2	3	E

APPENDIX V - SYNOPTIC METEOROLOGICAL OBSERVATIONS, 1959

Date	Time (local)	Air Temperature Dry (°F)	Air Temperature Wet (°F)	Wind Speed (knots)	Wind Dir. (°T)	Date	Time (local)	Air Temperature Dry (°F)	Air Temperature Wet (°F)	Wind Speed (knots)	Wind Dir. (°T)
October						October					
25	0158	1.0	0.4	4	ENE	28	0157	5.3	4.7	4	ENE
	0456	-0.2	-0.9	4	E		0458	9.7	8.7	4	E
	0756	0.1	-0.6	8	E		0759	10.1	9.3	2	E
	1056	4.4	2.4	9	ENE		1059	9.2	8.2	3	E
	1357	-1.5	-2.7	10	E		1358	5.3	4.7	4	ENE
	1658	-5.2	-5.6	8	E		1656	5.0	4.6	3	E
	1956	-3.9	-4.3	8	E		1959	6.9	6.1	3	E
	2258	6.0	4.3	4	E		2255	7.6	6.5	6	E
26	0155	2.8	1.6	6	E	29	0155	0.7	0.3	10	ESE
	0455	-7.9	-8.8	6	E		0455	8.0	7.1	9	ESE
	0756	-1.6	-2.7	10	E		0756	11.1	10.0	Calm	
	1059	9.2	7.8	13	SSE		1056	9.2	8.2	3	E
	1359	13.9	12.8	7	SW		1357	1.6	1.0	8	E
	1655	11.4	11.0	4	SE		1658	7.4	6.6	Calm	
	1955	12.7	11.6	8	SE		1955	4.3	3.5	Calm	
	2255	14.2	13.1	4	ESE		2255	-2.6	-3.1	9	E
27	0155	11.6	11.1	7	SE	30	0155	-8.6	-9.0	8	E
	0455	14.0	12.9	Calm			0455	-8.6	-9.1	9	E
	0755	12.9	12.1	Calm			0759	-8.3	-8.8	7	E
	1055	10.6	10.3	2	E		1057	-6.2	-6.9	7	ENE
	1358	10.9	10.2	Calm			1359	4.9	2.8	Calm	
	1656	8.9	8.4	3	E		1657	3.0	2.5	4	E
	1959	7.2	6.9	4	ENE		1957	0.1	-0.7	6	E
	2257	5.8	5.2	4	E		2258	1.9	1.6	Calm	

APPENDIX V - SYNOPTIC METEOROLOGICAL OBSERVATIONS, 1959

Date	Time (local)	Air Temperature		Wind	
		Dry (°F)	Wet (°F)	Speed (knots)	Dir. (°T)
October					
31	0157	0.0	-0.4	5	E
	0456	0.1	-0.6	7	ESE
	0759	5.2	4.4	8	E
	1056	5.2	4.3-	8	ESE
	1356	5.9	5.1	6	E
	1656	3.1	2.3	8	SE
	1955	2.7	1.9	6	SE
	2255	0.4	-0.3	2	E

APPENDIX VI

OCEANOGRAPHIC DATA - 1960

OCEANOGRAPHIC DATA, 1960

CAST 1 LOCATION Station 1
DATE 8 X 60 GMT 1932
DEPTH ——

Depth M	T °C	S ‰	σ_t
0	-1.28	——	——

CAST 2 LOCATION Station 1
DATE 9 X 60 GMT 1723
DEPTH ——

Depth M	T °C	S ‰	σ_t
0	-1.55	——	——

CAST 3 LOCATION Station 1
DATE 10 X 60 GMT 1930
DEPTH 10 M

Depth M	T °C	S ‰	σ_t
0	-1.54	32.30	26.01
3	-1.45	32.33	26.03
7	-1.45	——	——
10	-1.44	32.34	26.04

CAST 4 LOCATION Station 1
DATE 11 X 60 GMT 1340
DEPTH 9 M

Depth M	T °C	S ‰	σ_t
0	-1.55	32.30	26.01
2	-1.55	32.32	26.02
6	-1.55	32.32	26.02
9	-1.55	32.32	26.02

CAST 5 LOCATION Station 1
DATE 14 X 60 GMT 1520
DEPTH 8 M

Depth M	T °C	S ‰	σ_t
0	-1.59	——	——
2	-1.54	32.31	26.02
6	-1.53	——	——
8	-1.52	——	——

CAST 6 LOCATION Station 3
DATE 14 X 60 GMT 2000
DEPTH 15 M

Depth M	T °C	S ‰	σ_t
0	-1.64	32.25	25.97
5	-1.54	——	——
10	-1.54	32.25	25.97
15	-0.86	32.57	26.20

CAST 7 LOCATION Station 1*
DATE 14 X 60 GMT 2100
DEPTH 9 M

Depth M	T °C	S °/oo	σ_t
0	-1.55	32.35	26.05
9	-1.55	——	——

CAST 8 LOCATION Station 1*
DATE 15 X 60 GMT 1510
DEPTH 8 M

Depth M	T °C	S °/oo	σ_t
0	-1.58	32.28	25.99
2	-1.56	32.28	25.99
6	-1.57	32.44	26.12
8	-1.59	32.47	26.14

CAST 9 LOCATION Station 2
DATE 15 X 60 GMT 2000
DEPTH ——

Depth M	T °C	S °/oo	σ_t
0	-1.77	——	——
10	-1.22	——	——
15	-0.77	32.47	26.12
20	-0.65	32.76	26.35

CAST 10 LOCATION Station 1*
DATE 15 X 60 GMT 2055
DEPTH ——

Depth M	T °C	S °/oo	σ_t
0	-1.68	32.52	26.19

CAST 11 LOCATION Station 1
DATE 17 X 60 GMT 1440
DEPTH 9.5 M

Depth M	T °C	S °/oo	σ_t
0	-1.52	32.55	26.21
3	——	32.55	——
6	-1.44	32.58	26.22
9	-1.47	32.59	26.24

CAST 12 LOCATION Station 1
DATE 18 X 60 GMT 1445
DEPTH 9.5 M

Depth M	T °C	S °/oo	σ_t
0.0	-1.52	32.54	26.20
3.0	-1.42	32.63	26.26
6.5	-1.17	——	——
9.5	-1.16	32.67	26.29

* Bubbling system in operation

CAST 13
DATE 19 X 60
DEPTH 10 M
LOCATION Station 1
GMT 1420

Depth M	T °C	S °/oo	σ_t
0	-1.52	32.46	26.14
3	-1.52		
7	-1.50	32.66	26.30
10	-1.46	32.68	26.32

CAST 14
DATE 20 X 60
DEPTH 10 M
LOCATION Station 1*
GMT 1525

Depth M	T °C	S °/oo	σ_t
0	-1.53	32.75	26.37
3	-1.53	—	—
8	-1.34	32.76	26.37
10	-1.32	32.76	26.37

CAST 15
DATE 20 X 60
DEPTH 9.5 M
LOCATION Station 1
GMT 1815

Depth M	T °C	S °/oo	σ_t
0.0	-1.65	32.54	26.20
2.5	-1.62	32.69	26.32
7.5	-0.82	32.84	26.42
9.5	-0.73	32.93	26.49

* Bubbling system in operation

CAST 16
DATE 21 X 60
DEPTH 10 M
LOCATION Station 1
GMT 1435

Depth M	T °C	S °/oo	σ_t
0	-0.94	32.96	26.53
4	-0.96	33.07	26.62
8	-0.98	33.09	26.63
10	-0.98	33.11	26.65

CAST 17
DATE 22 X 60
DEPTH 9.5 M
LOCATION Station 1
GMT 1425

Depth M	T °C	S °/oo	σ_t
0.0	-1.26	32.72	26.33
3.5	-1.20	32.83	26.42
6.5	-1.14	32.85	26.44
9.5	-1.14	32.86	26.45

CAST 18
DATE 23 X 60
DEPTH 11 M
LOCATION Station 1
GMT 1817

Depth M	T °C	S °/oo	σ_t
0	-1.57	32.75	26.37
4	-1.42	32.86	26.45
8	-1.42	32.86	26.45
11	-1.42	32.86	26.45

CAST 19 LOCATION Station 1
DATE 24 X 60 GMT 1523
DEPTH 9.5 M

Depth M	T °C	S ‰	σ_t
0.0	-1.40	32.96	26.53
3.5	-1.40	—	—
6.5	-1.40	32.97	26.54
9.5	-1.40	32.97	26.54

CAST 20 LOCATION Station 1
DATE 25 X 60 GMT 1445
DEPTH 9.5 M

Depth M	T °C	S ‰	σ_t
0.0	-1.39	32.97	26.54
2.5	-1.38	32.97	26.54
6.5	-1.38	32.97	26.54
8.5	-1.38	32.97	26.54

CAST 21 LOCATION Station 1
DATE 26 X 60 GMT 1435
DEPTH 8 M

Depth M	T °C	S ‰	σ_t
0	-1.68	32.82	26.43
2	-1.65	32.82	26.43
6	-1.64	32.82	26.43
8	-1.64	32.82	26.43

* Bubbling system in operation

CAST 22 LOCATION Station 1*
DATE 26 X 60 GMT 1815
DEPTH 9.5 M

Depth M	T °C	S ‰	σ_t
0.0	-1.68	32.81	26.42
3.5	-1.68	32.81	26.42
6.5	-1.68	32.81	26.42
9.5	-1.68	32.81	26.42

CAST 23 LOCATION Station 1
DATE 27 X 60 GMT 1555
DEPTH 8.5 M

Depth M	T °C	S ‰	σ_t
0	-1.67	32.82	26.43
3	-1.66	32.82	26.43
6	-1.65	32.83	26.44
8	-1.65	32.83	26.44

CAST 24 LOCATION Station 1
DATE 28 X 60 GMT 1425
DEPTH 9 M

Depth M	T °C	S ‰	σ_t
0	-1.68	32.82	26.43
5	-1.66	32.82	26.43
9	-1.62	32.82	26.43

CAST 25 LOCATION Station 1
DATE 29 X 60 GMT 1435
DEPTH 9 M

Depth M	T °C	S °/oo	σ_t
0	-1.81	32.82	26.43
3	-1.80	32.82	26.43
6	-1.79	32.82	26.43
9	-1.79	32.82	26.43

CAST 26 LOCATION Station 1
DATE 30 X 60 GMT 1520
DEPTH 9.5 M

Depth M	T °C	S °/oo	σ_t
0.0	-1.82	—	—
3.5	-1.77	32.81	26.42
7.5	-1.77	—	—
9.5	-1.77	32.83	26.44

CAST 27 LOCATION Station 1*
DATE 31 X 60 GMT 1425
DEPTH 9.5 M

Depth M	T °C	S °/oo	σ_t
0	-1.82	32.91	26.50
3	-1.82	32.87	26.47
9	-1.77	32.88	26.48

* Bubbling system in operation

CAST 28 LOCATION Station 1
DATE 31 X 60 GMT 1830
DEPTH —

Depth M	T °C	S °/oo	σ_t
0	-1.80	—	—

CAST 29 LOCATION Station 1*
DATE 31 X 60 GMT 1850
DEPTH 8 M

Depth M	T °C	S °/oo	σ_t
0	-1.81	32.84	26.45

CAST 30 LOCATION Station 1*
DATE 1 XI 60 GMT 1445
DEPTH 11 M

Depth M	T °C	S °/oo	σ_t
0.0	-1.82	—	—
3.5	-1.82	—	—
7.5	-1.82	—	—
10.5	-1.82	—	—

CAST 31 LOCATION Station 1*
DATE 1 XI 60 GMT 1748
DEPTH ——

Depth M	T °C	S ‰	σ_t
0	-1.82	32.85	26.45

CAST 32 LOCATION Station 1*
DATE 2 XI 60 GMT 1435
DEPTH 11 M

Depth M	T °C	S ‰	σ_t
0	-1.86	32.86	26.46
4	-1.85	——	——
8	-1.83	——	——

CAST 33 LOCATION Station 1*
DATE 4 XI 60 GMT 1407
DEPTH 11 M

Depth M	T °C	S ‰	σ_t
0	-1.78	32.92	26.51
4	-1.78	32.92	26.51
8	-1.78	32.92	26.51
11	-1.78	32.92	26.51

* Bubbling system in operation

CAST 34 LOCATION Station 1*
DATE 5 XI 60 GMT 1520
DEPTH 11 M

Depth M	T °C	S ‰	σ_t
0	-1.82	32.96	26.54
4	-1.82	32.96	26.54
8	-1.82	——	——
11	-1.81	32.93	26.52

CAST 35 LOCATION Station 4
DATE 5 XI 60 GMT 1705
DEPTH ——

Depth M	T °C	S ‰	σ_t
0	-1.80	32.96	26.54

CAST 36 LOCATION Station 1*
DATE 6 XI 60 GMT 1525
DEPTH 11.5 M

Depth M	T °C	S ‰	σ_t
0.0	-1.84	32.98	26.56
3.5	-1.83	——	——
8.5	-1.83	32.94	26.53
11.5	-1.82	32.94	26.53

CAST 37 LOCATION Station 4
DATE 6 XI 60 GMT 1710
DEPTH 5.5 M

Depth M	T °C	S °/oo	σ_t
0	-1.83	32.96	26.54
5	-1.83	32.98	26.56

CAST 38 LOCATION Station 1*
DATE 7 XI 60 GMT 1425
DEPTH 11.5 M

Depth M	T C	S /oo	σ_t
0.0	-1.83	—	—
4.5	-1.83	32.92	26.51
8.5	-1.83	—	—
11.5	-1.83	32.95	26.54

CAST 39 LOCATION Station 4
DATE 7 XI 60 GMT 1530
DEPTH —

Depth M	T °C	S °/oo	σ_t
0	-1.83	33.06	26.62

APPENDIX VII

MONTHLY WEATHER SUMMARY

THULE AIR BASE - 1960

APPENDIX VII - MONTHLY WEATHER SUMMARY, 1960

Date	Air Temperature (°F) Max.	Min.	Wind Max. Speed (m.p.h.)	Dir.	Date	Air Temperature (°F) Max.	Min.	Wind Max. Speed (m.p.h.)	Dir.
October					October				
1	34	25	20	ENE	25	31	28	36	ESE
2	30	24	20	ESE	26	31	27	34	E
3	28	21	35	SE	27	33	14	33	ESE
4	27	23	24	SSE	28	32	23	27	SE
5	27	11	17	ESE	29	30	15	32	SE
6	17	8	14	E	30	22	10	12	NW
7	17	11	14	W	31	17	- 4	15	E
8	22	9	11	E					
9	21	9	11	E	November				
10	27	16	16	E	1	18	0	28	SSE
11	40	27	24	E	2	20	9	31	ESE
12	32	23	35	W	3	22	18	50	SE
13	23	16	39	W	4	21	18	37	SE
14	17	3	14	W	5	18	8	13	ESE
15	15	1	18	ESE	6	18	7	21	S
16	27	15	35	ESE	7	12	4	15	SSE
17	26	13	16	SE	8	11	-12	23	WNW
18	22	10	9	E	9	- 4	-13	15	ESE
19	11	1	13	E	10	5	- 6	13	ESE
20	32	11	28	E	11	9	3	14	NW
21	39	28	51	E	12	11	- 4	12	WSW
22	29	13	22	ESE	13	5	-12	14	ESE
23	33	10	33	ESE	14	16	- 6	17	E
24	34	29	48	ENE	15	20	7	15	NNW

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Appendixes

Presents a model to describe retardation of ice growth based on the air-bubbling system installed by MSTSLANT at Thule, Greenland during the fall of 1959. Oceanographic and meteorological data obtained during the fall of 1959 and 1960 are also presented.

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2. Ice potential
3. Hydrodynamics
4. Engineering, underwater
5. Oceanography
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ii. author: Charles W. Senior
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Bibliography

Appendixes

Presents a model to describe retardation of ice growth based on the air-bubbling system installed by MSTSLANT at Thule, Greenland during the fall of 1959. Oceanographic and meteorological data obtained during the fall of 1959 and 1960 are also presented.

1. Air-bubbling in retarding ice formation
2. Ice potential
3. Hydrodynamics
4. Engineering, underwater
5. Oceanography
i. title: Study of Oceanographic Conditions as Related to Project Polynya
ii. author: Charles W. Senior
iii. H. O. TR-80